Transtibial Prosthesis

1-1 Background:

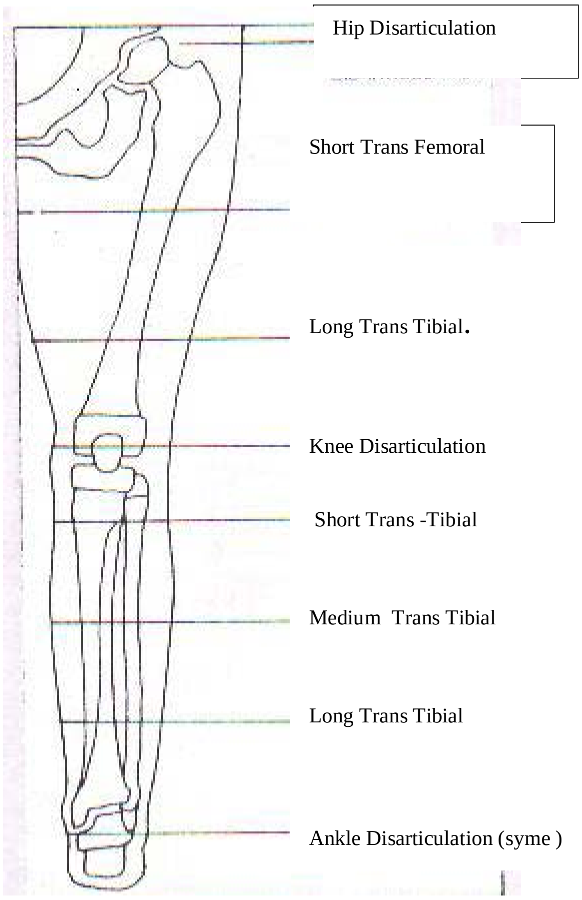
In 1696, a Dutch surgeon produced the first known non-locked Trans-Tibia prosthesis. It contained external hinges that permitted motion about the ankle and a leather cuff that was load bearing. It was a great advancement from all previous designs that focused on cosmetics rather than function. The importance of replicating physiologic and anatomical function was furthered in 1800 by an inventor in London. The new design incorporated the position of the foot in normal gait by utilizing a cable and pulley system attached to the knee joint. When the knee was flexed, the foot was moved into dorsiflexion, and when the knee was extended the foot was moved into plantar flexion. The advancement over the next 150 years was fairly slow, occasionally spurred on by the influx of amputees during wartime. However, in 1946, the Surgeon General of the United States formed a team of engineers and surgeons, named the American Orthotics and Prosthetics Association, to begin work on furthering the science of prosthetics and orthotics. The modern era of state of the art design of prostheses for specific function was ushered in.

Today, transtibial amputees have a variety of full functioning options for their Prosthesis. Most insurance plans will cover the costs associated with purchasing, fitting and maintaining the devices. Likewise, transtibial-amputated athletes have an equal number of options available to fit their particular sport. Although a high performing sport specific prosthesis may cost 3 to 10 times that of a normal Prosthesis and may not be covered by insurance, a better design is necessary in order for the amputee to continue to perform athletics at a high level. While no manufacturer has been able to completely replicate the native function and motion of the human ankle/ foot joint, several manufacturers and researchers have identified a few important mechanical properties for optimizing the performance of a transtibial Prosthesis for each sport. One researcher[2] identified 18 possible variables during gait that could be influenced by foot/ankle prosthesis design.

Casting Guidelines

1-2 Amputation levels:-

1. Hip Disarticulation.
2. Short Trans Femoral .
3. Long Trans Femoral
4. Knee Disarticulation
5. Short Trans -Tibial
6. Medium Trans Tibial
7. Long Trans Tibial.
8. Ankle Disarticulation (syme)



1-3 Preparation Before Casting :-

The Tools present are:-

a) Meter stick.
b) Measurement chart.
c) Indelible Pencil.
d) Measuring Tape.
e) Goniometer.
f) Vernier Caliper.
g) Clean Water in a Clean jar .

h) Vaseline.

i) P.O.P Bandages and Stockinet's.

j) Scissor and Knife.

k) Plumb .

l) Protecting Strap for Knife cutting.

m) Cleaning Towel for the Patient, Equipment and Tools.

1-4 Examination of the Hip:-

A. Range of the Motion :- Normal Range of Motion are :-

Flexion is 130^0

Extension is 30^0

Abduction is $45 – 50^0$

Adduction $20 – 30^0$

The most common problem with range of movement at hip joint for amputees is hip flexion contracture. This can accurately be measured by using **(Thomas Test .)**

B. Muscle Strength :-

Strength of hip flexion muscles .

Strength of hip extensor muscles.

Strength of hip abduction muscles.

Strength of hip adduction muscles.

1-5 Measurement:-

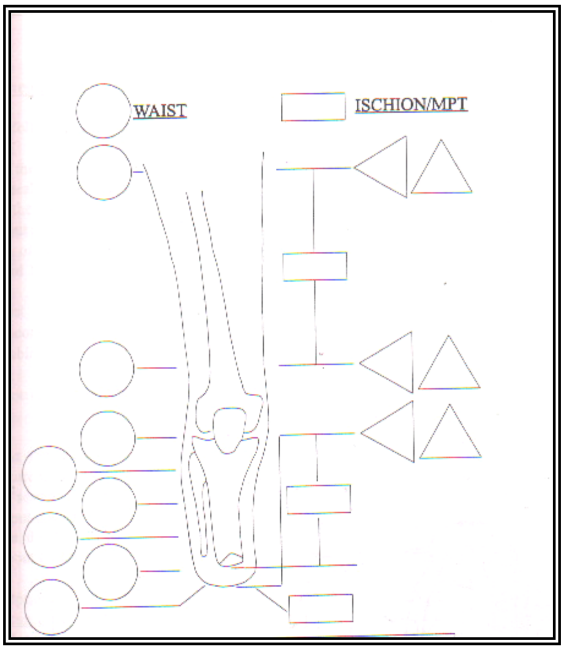
1-5-1 Stump measurement :- The measurements can be of two or three dimensions, in practice we are recording mainly two dimensions measurement . the cast is a three dimensions measurement . the accuracy depends on the subcutaneous tissue, musculature, size of stump, and the skill and experience of the prosthetist with regard to how much tension to apply on measuring tape.

There are two dimensions measurements :-

1. Liner measurement :- Circumferences, diameter and length or height as illustrated in fig.

(measurement assessment chart).

2. Angular measurement :- usually for contracture of the stump.



1-5-2 Diameters

The following measurement are needed to aid in medication of the plaster cast :-

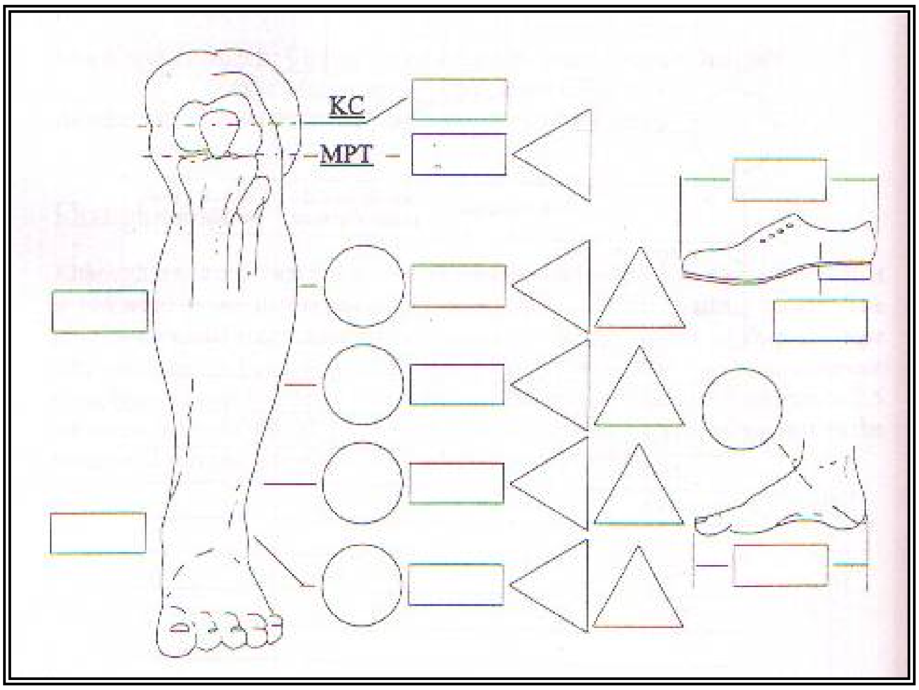
a. At patellar tendon level an anterior posterior measurement taken from mid-tendon to the popliteal region between the medial and lateral hamstring. This should be taken with the knee in 10 -15 degree flexion. Here you can take two diameters, one without pressure and one with firm compression this way it helps you to judge the value of the force used . the difference between those two diameters should be around **(1.2 to 1.5 cm).**

b. Just above the femoral condoyle in **Medial – Lateral** measurement to be used for the supracondylar suspension . **(Note:- If you are making a supracondylar socket, you can take the anterior – posterior measurements at that level)**.

c. At the patellar level the **Medial – Lateral** measurement of the femoral condyle, to it's widest point.

(Usually taken with out compression , there are soft tissue, the tissue should be compressed to about half of it ' s thickness) .

d.Diameter measurements of the sound leg are useful for cosmetic shaping of the prosthesis.



1-5-3 Length :- The most important length measurements are :-

A) Length o stump taken from the **Tibia – Plateau** to the most distal aspect of the stump **.**

B) Length o stump taken from the **Axis of the Rotation of the Knee** to the most distal aspect of the stump **.**

C) Length o stump taken from the **Tibia – Plateau** to the most distal end of the tibia .

D) For the sound leg take measurement from the center knee (from the axis rotation of the knee) to the floor. The amputee should be in seated position , the sound leg foot is foot flat and his knee is flexed 90 degrees.

1-6 Trans - Tibial Casting Procdedure:-

1-6-1 Aim :-

The aim of fitting to create a good Trans – Tibial socket to achieve comfortable , total contact and carrying most of the patients weight on the area of the sump which can tolerate pressure .

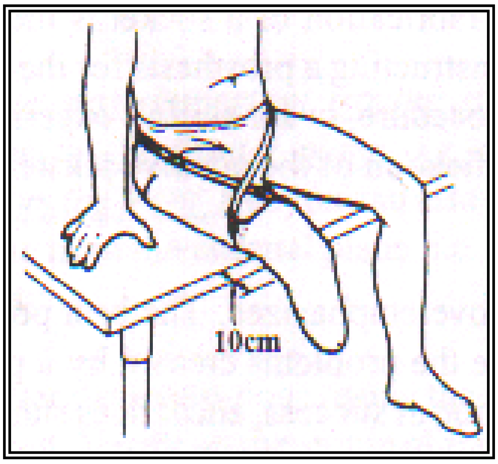
1-6-2 Casting Technique:-

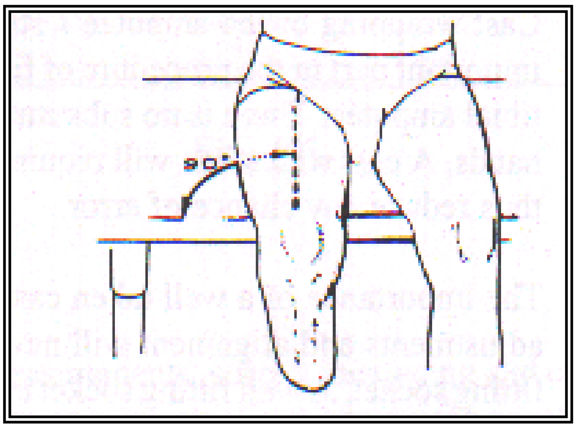
Cast wrapping of amputee's stump for fabrication of socket is the most important part in the procedure of fitting and constructing a prosthesis for the trans – tibial amputee .

1-6-3 Casting Procedure:-

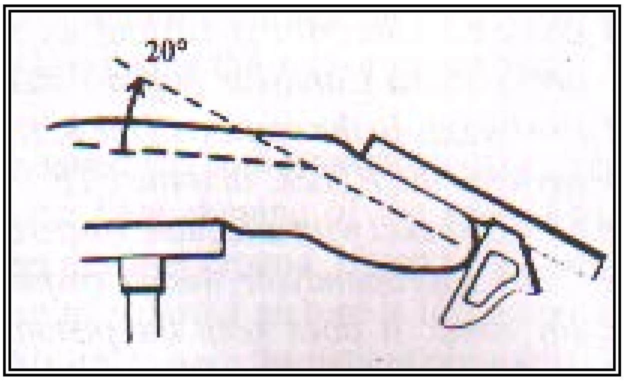
Before you starting , make sure you have the material and tools required for casting.

Just after taken the measurement the amputee is still seated on the table with his thigh supported the back of his knee approximately 10 cm as illustrated in fig. from the edge of the table.

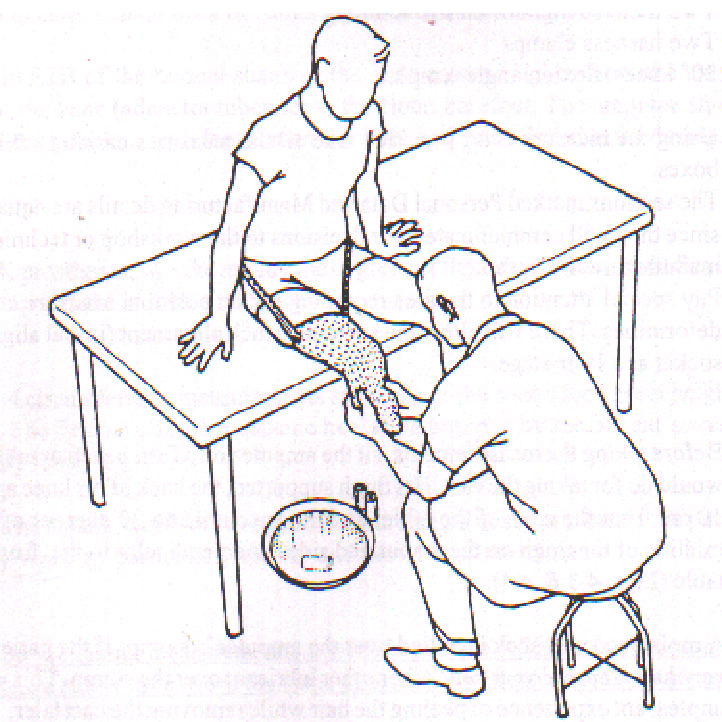




and the knee is 20 degree of flexio as shown in fig. During the entire wrapping sequence,the knee joint should be held in position of 20 degree of flexion so as emphasize bony prominence .

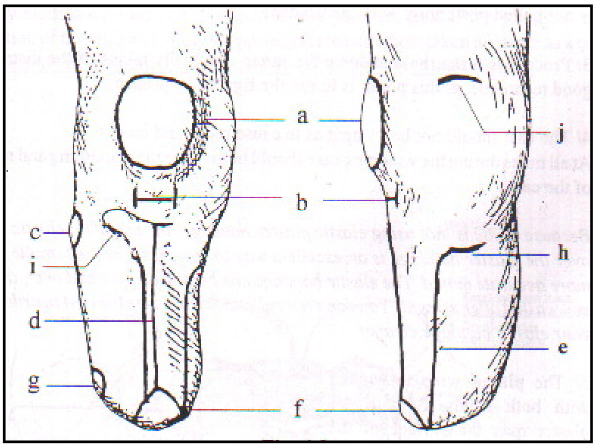


<u>1-6-4 To obtain better cast</u> :-Position your self in front of the stump and sit lower than amputee.



1-6-5 Reference Marks:-

- **a-** Out line of the patella.
- **b-** Mid of the patellar tendon (mark with a horizontal line midway between the distal poleof patella and the superior border of the tibial tubercle .
- **c-** Out line the head of the fibula.
- **d-** Tibial Crest.
- **e-** Medial border of the tibia.
- **f-** Distal end of the tibia.
- **g-** Distal end of the fibula.
- **h-** The medial flare of the tibia condyle.
- **i-** The lateral flare of the tibia condyle.
- **j-** The femoral epicondyles.



1-6-6 Casting Procedure:-

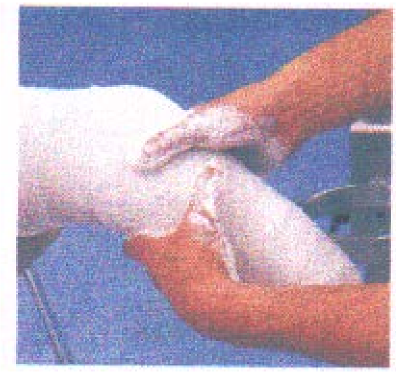
1. Use 15 -20 Cm of P.O.P.

2. Wrap the P.O.P around the sump carefully at right angle to the longitudinal axis until the plaster is three layer thick. .

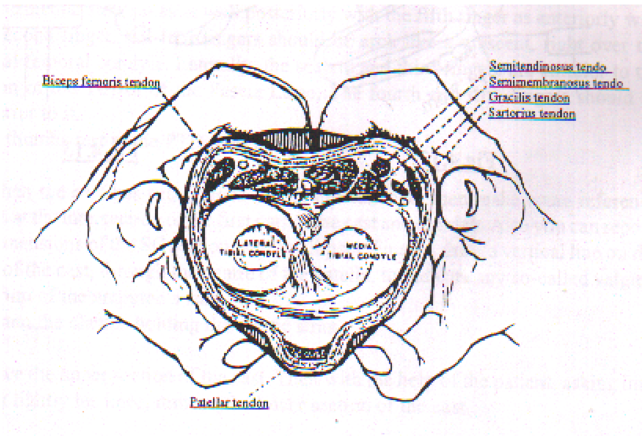
3. Proceed to wrap the cast down the stump eventually taking in the distal end.. A good technique at this point is to use the figure **8** approach.

4. The cast should not be so tight as to cause racks and lines .

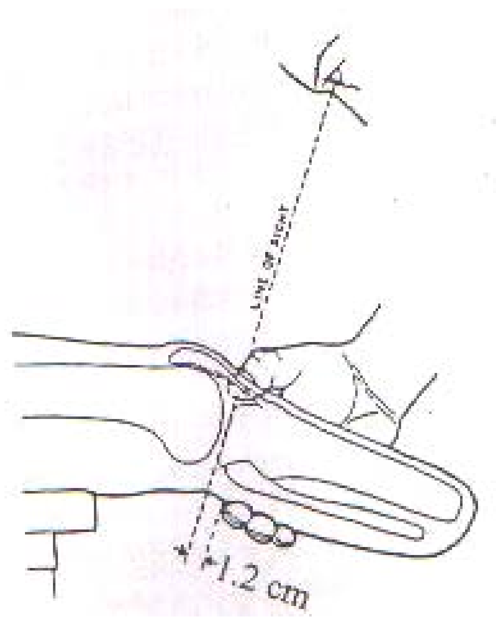
5. The P.O.P must be worked with both hand. Smooth the P.O.P over the surface of the stump by moving both hands from anterior to posterior around the stump and from distal to the proximal



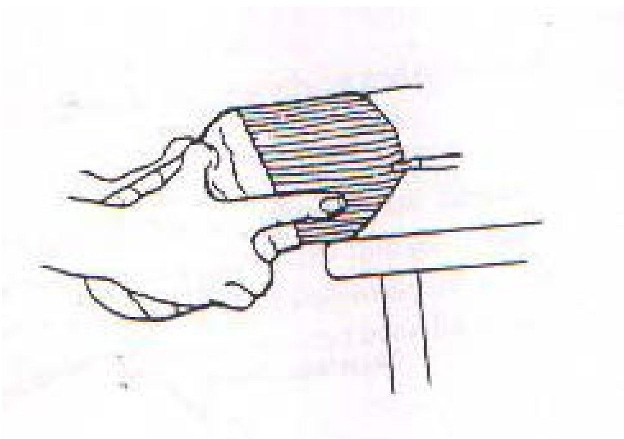
6. Position the thumbs on the patellar tendon at 45 degree angle with the long axis of tibia .



7. The upper 3rd finger should approximately 1.2 cm distal to the thumbs. Be sure the finger tips are centered in the popliteal are



8. The remaining finger must exends on each side of the wrapand helps to resist any tendency toward mediolateral bulging.

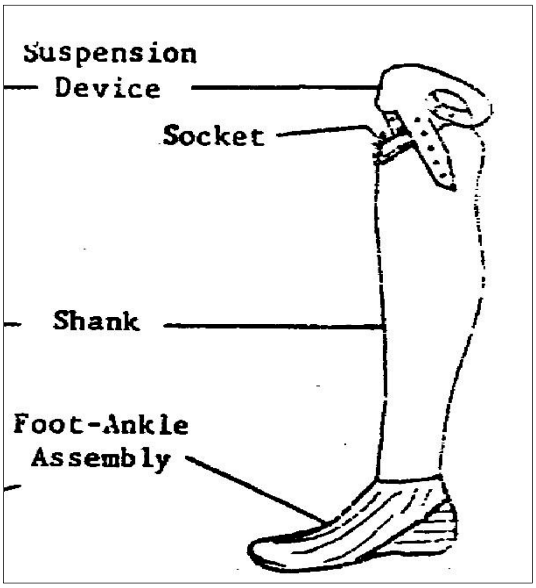


Note :- You should press hard enough to get identification of the spots.Good care should be taken to keep the M-L of the cast as close possible to the M – L of the stump.

1-7 Prosthesis Components :-

1. Suspension Device.
2. Socket (hard socket , soft socket).
3. Shank (wooden , metal , poly propelyn)
4. Foot –Ankle assembly.
5. Foot.(S.A.C.H , Single – Axis,

Multi- Axis, Flexible – Axis and Enrgy-Storing)



1-8 Type of Prosthesis :-

1. Temporary Prosthesis. (the socket made from many type of material such as P.O.P).

2. Conventiol prosthesis . (the socket made of wooden or lather and the shank made of wooden)

3. Modelar Prosthesis. (the socket made of Plastic which is made from composite material
(lamination) or made from propelyne material and the shank made from metal or polypropelyne.)

1-9 Temporary Prosthesis:-

Spicial prosthesis used for rehabilitationof the amputee during the period from surgery untill of the permanent prosthesis.

The Temporary prosthsis use :-

a) Direct after the surgery by using the rigid dressing (P.O.P).

b) After removing the sticks (~ weeks after operation)

1-9-1-Main type ofTemporary Prosthesis:-

A. Easy to (Puton and Put off)

B. Light weight.

C. Could accepet defferen size of stump.

1-9-2Goals of using Temporary Prosthesis:-

1. To prevent odema.
2. To help the amputee to stand and balance.
3. To prevent any atrophy and contracture .
4. TEo prepare him for permanent prosthesis

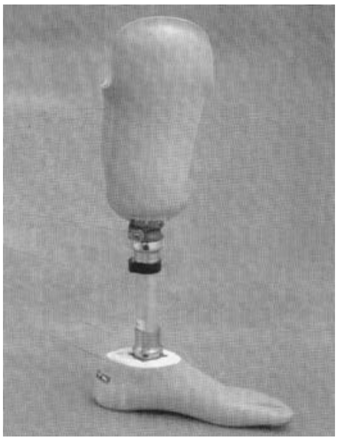
1-10Suspension System :-

Fitting of a socket designed to satisfy the above criteria (معيار) and the specification that knee function be as near to the normal as possible defines the requirements of the suspension system . It must hold the prosthesis on the stump during the **Swing Phase** , **resisting gravity and inertia forces of a relatively low magnitude.** It must also allow without restriction the normal movement of the knee, it may, in addition be used a safety control against hyperextension of the knee during the early part of the **Stance Phase.**

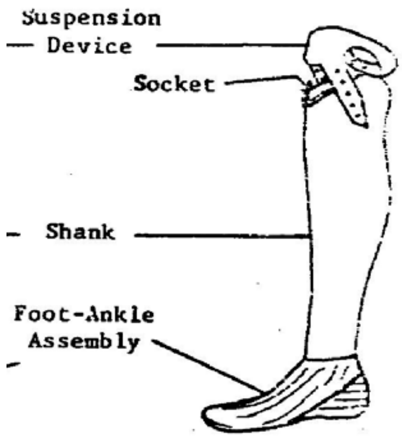
1-10-1 Type Of Suspension are:-

1. **Cuff Suspension.**

The basic **PTB** prosthesis is suspended by means of a **supracondylar cuff** as shown in Fig .2-4 which is attached to the socket in the **posteromedial** and **posterolateral areas** and encircles (يطوق) the thigh just above the femoral epicondyles and patella. The **supracondylar cuff** serves primarily to retain the prosthesis on the stump, it provides only slight assistance for **mediolateral** stability but does resist forces that tend to force the knee into hyperextension . Most amputees, with possible exception of those with very short or painful stumps, fined the stump socket pressures well within their tolerance (المقدرة على) with this type suspension.



Prosthesis with KBM

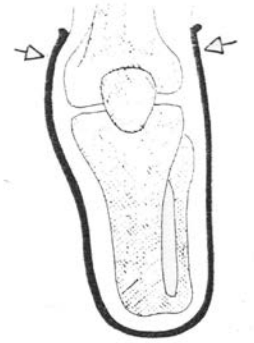


supracondylar Cuff Suspension

2. Superacondylar System (KBM) :-

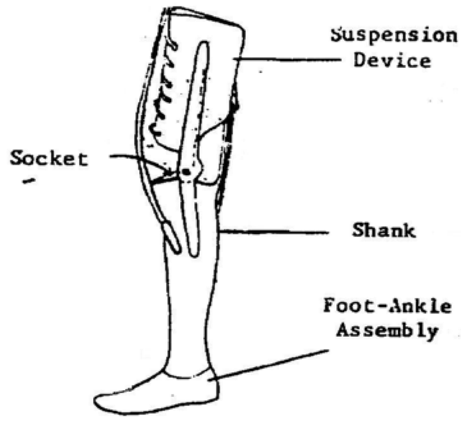
Superacondylar suspension employs medial and lateral walls higher than those of the original **PTB** designed as shown in fig. The higher walls encompass (يشمل) the femoral epicondyles from the medial and the lateral side . The highest of the medial and the lateral side about **9-10 cm** above the mechanical axis , this type of suspension depending on the shape of condoyle of the patient it must be a good shape also the patient have a good fitting and he has ability to walking and not afraid from using the prosthesis.

3. Supracondy lar / Superapatellar System (SC/SP):-



4. Thigh Corset :-

The thigh corset is attached to the socket and shank by the side bars and knee joint assembly as illustrated in Fig .In addition to suspending the prosthesis, the corset supports part of the body weight provides mediolateral stability and increases sensory feedback. A short stump, lack of muscular control and joint instability it will be necessary to add to the prosthesis a corset with side joint. It is interesting the biomechanical implications. The influence on the mediolateral stability is rather easily recognized . In Fig 2-7 it was demonstrated that **M** and **L** representing the summation of medial and lateral forces, were required in the position shown, to resist the toppling effect of the body mass about support point .

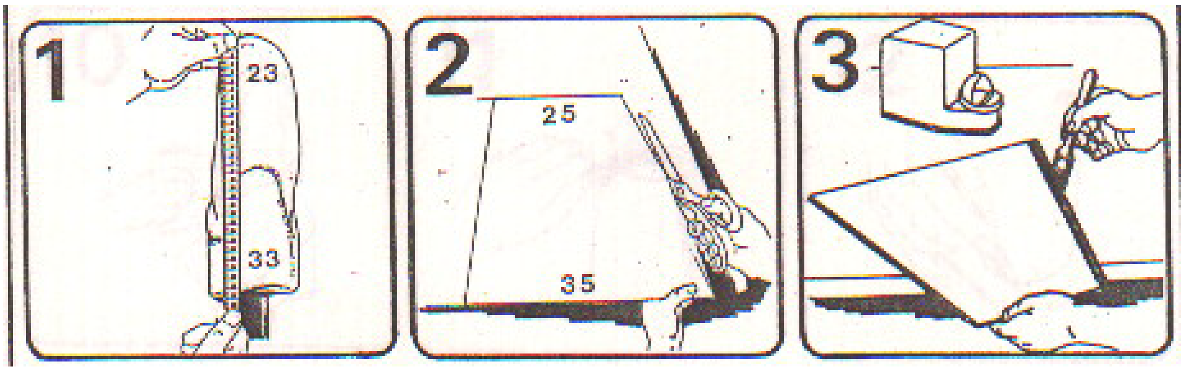


Prosthesis with Thigh Corset Suspension

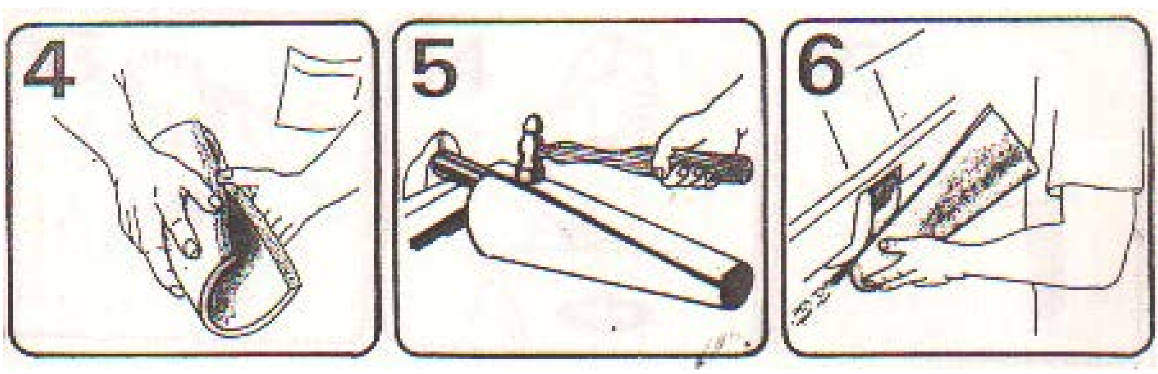
Fabrication of Soft and Hard socket

3-1 <u>Fabrication of Soft socket:-</u>

1. place the stump model (positive) in the bench vise with model – held in a vertical position.
2. Cut a piece of P- light material (3, 4 or 5 thickness) with 5 cm longer than the length of model and 5 cm wider at the tope and bottom than the distal and proximal circumferences .
3. Make grinding at the long side with taper shape. And put glue on each side



4. Put each side on other to be adhesion.
5. place the conical P-Lite on bench vise with horizontal position use the hammer and hammered the glued to be adhesion side.
6. Make grinding for adhesion side until to be smooth .



7. Place the conical PE-Lite in the oven about 35 minute.
8. Put on the conical P-Lite to the stump model.

9. Connecting the upper end by a thread

.

10. Tighten the model with bandage to take the PE-Lite the same shape of stump.

11. Cut the distal end and make grinding to be smoothing .

12. Cut a circle to make cape.

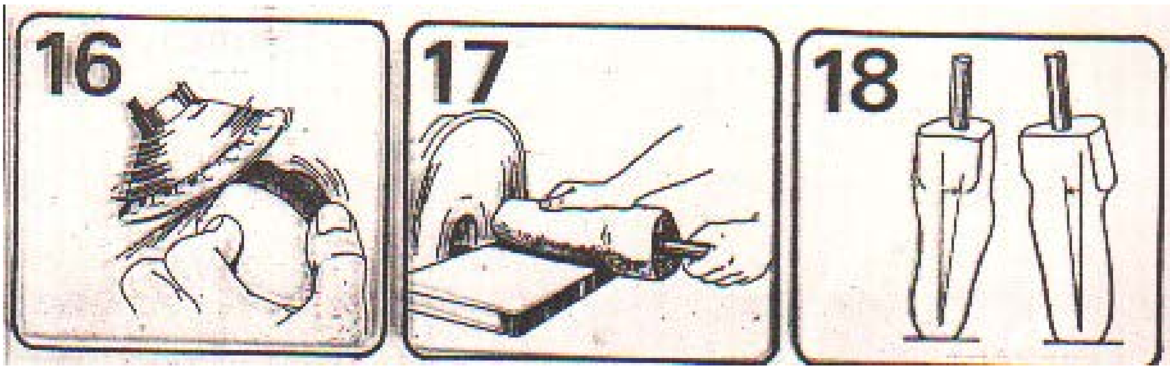
13. Make grinding to the end of circle and glued it .

14. Use hot air gun to thrust hot air on the glued area of the circle .

15. Put the cape on the distal end and welded.

16. , **17 –**Make grinding to the tope end to be smoothing .

18 – Then the model ready to Plastic modification Hard Socket .



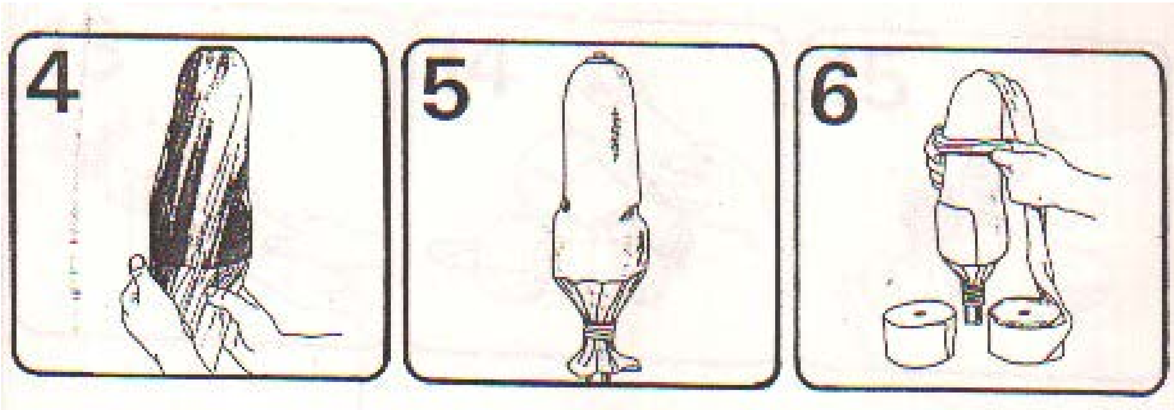
3-2 Fabrication of Hard socket Lamination Method:-

The plastic shell of the Below – Knee socket is fabricated over the soft insert. To protect the insert from the plastic, the insert PE-Lite (soft socket) is covered by P.V.A. sleeve, capped at the end.

1. Fixed the model with PE-Lite soft socket in the bench vise with model – held in a vertical Position and put the socket adepter on the tope of distal end of the model center .
2. Check the place of the socket adepter.
3. The P.V.A. either ready or fabricated .

4. To fabricated two tapered P.V.A. sleeves to the dimension from the top circumference and lower circumference and add 25 cm to the top end and 25 cm to the lower end
5. Prepare the humid or moister P.V.A.
6. Coat the outer surface of the socket liner liberally with talc . stretch the P.V.A. sleeve over

the model and insert, then trim around the distal end where the P.V.A. sleeve no longer makes contact with the insert..



7. Pull a sheet of P.V.A. over the end cap bonded to the P.V.A. sleeve.

8. Tie off around the mandrel and trim all loose material, the P.V.A. covering over the insert prevents adhesion between the insert and the socket and allows removal of the insert of the insert of the insert from the final socket.

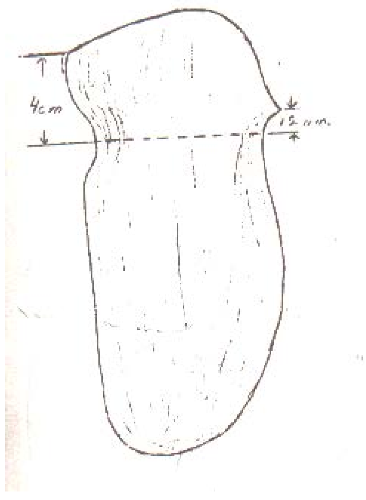
9. The Reinforcement Material used to fabricate the composite hard socket :-

- **a -** **6** Layers Perl on stockinet , 8-12 cm width depending up on circumference.
- **b -** 2 Layers of Fiberglass stockinet with same width of Perl on stockinet use from 8-12 cm depending up on circumference.
- **c -** Carbon Fiber put on the end of the socet.
- **d -** Some time may be used Decron Fiber.

10. Stretch the second P.V.A. sleeve over the lay-up. Tie off the sleeve at the proximal end around the mandrel.

11. Prepare from 250 – 400 , depending on socket size .

12. The Plastic resin are :-

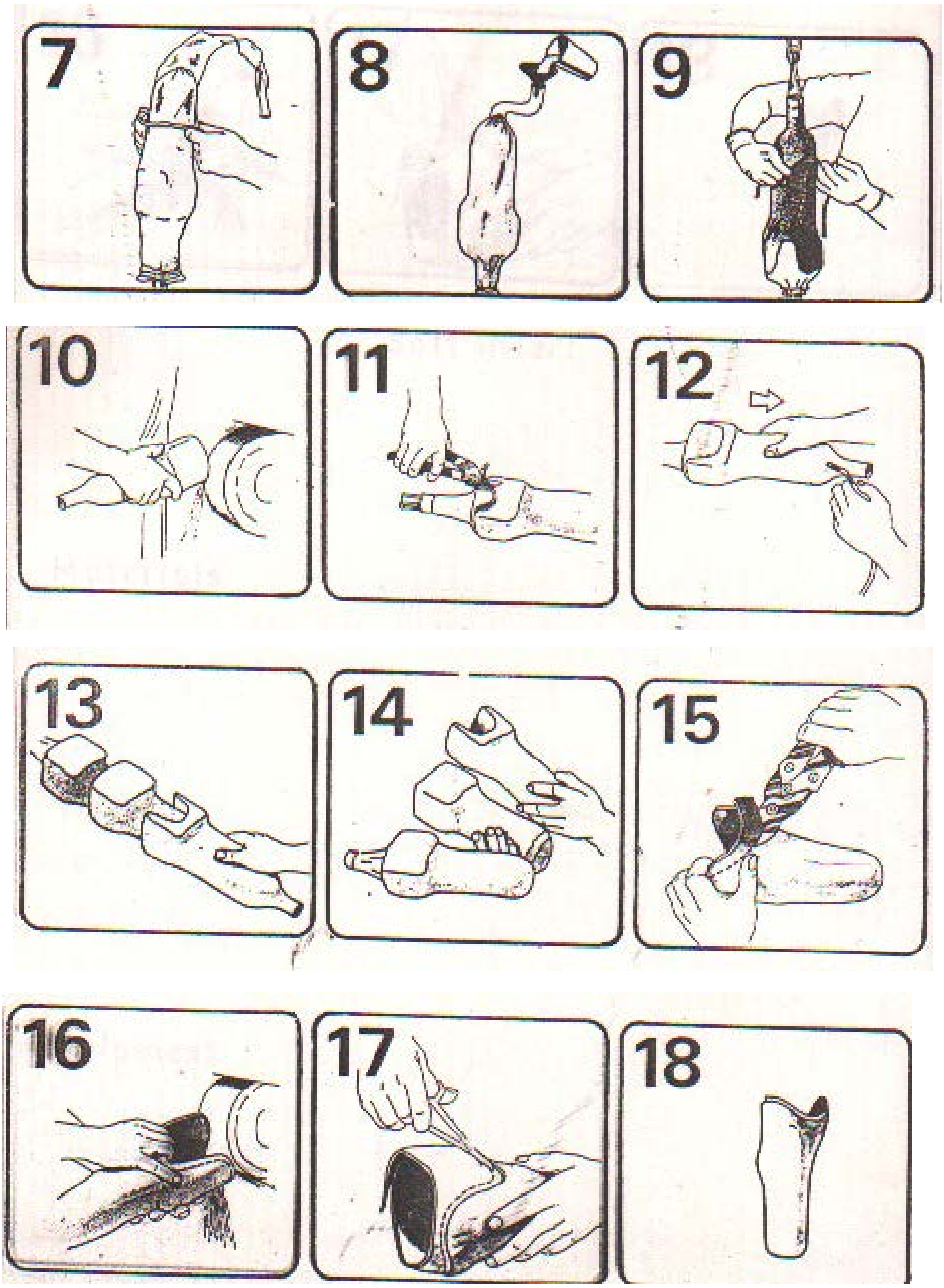


I - Resin type 617H19 DEGAPLAST Lamination Resin.

617H19 DEGAPLAST 103 Flexible.

II – Quantity : 250 - 400 g.

III – Hardener :- 3 %.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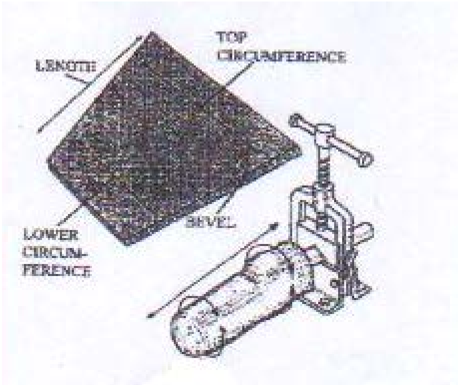
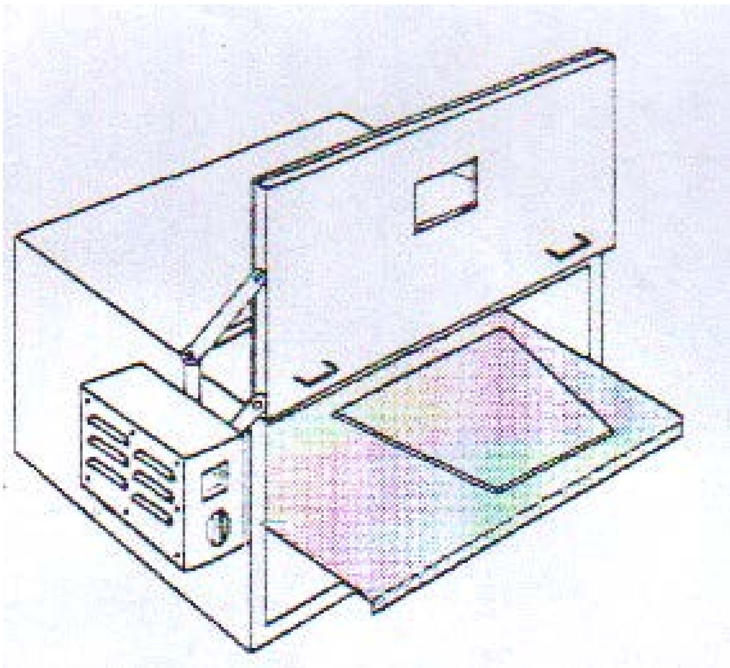
3-3 <u>Fabrication of Hard socket Polypropylene Method:-</u>

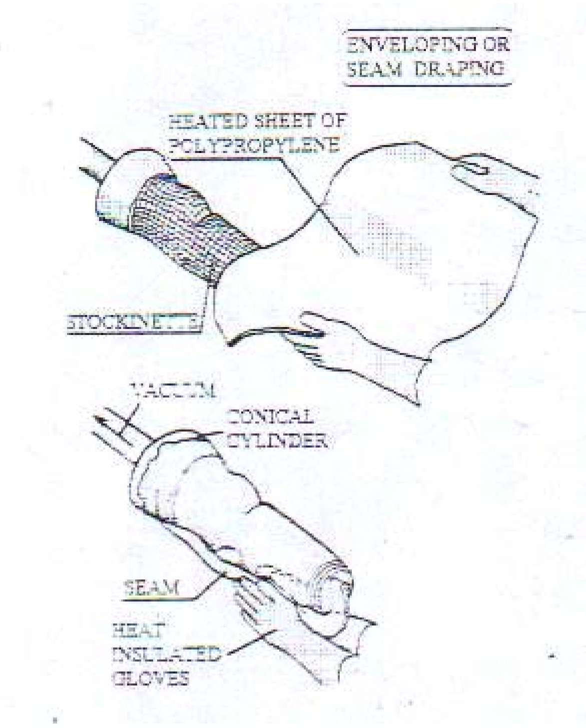
1. Prepare a sheet of polypropylene with the dimensions depending upon the length of the model and the upper and lower circumference and add to the each dimension 3 cm.



2. Put the piece of polypropylene sheet inside the oven and fixed the thermostat **170 c^{o}.** It was heated for about 35 mint as shown in fig.



3. The heated sheet of polypropylene was is then draped over the model cast taken a conical cylindrical shape and the ends pushed together underneath in such a way that it becomese sealed and suction can take hold as illustrated in fig.



4. After 15 mint take the polypropylene socket away from the model cast and clean it and make grinding to become smooth and ready to assembly .

4-1Prosthetic Shank:-

The Function of the Shank are :-

1. To hold the foot and socket position.
2. To transfer the load from the socket to the foot and transfer the ground reaction force from the foot to the socket.
3. To provide cosmetic .

4-1-1 Type of shank :-

A. **Exoskeletal Shank :-** the structure that carries the load is on the outside of the leg. So effectively the cosmetic cover has to be strong enough to carry the loads of the patient in day to day activity. The major materials used are composite plastic **GRP**, aluminum or polypropylene. In the case of composite plastic **GRP** the structure is usually filled with wood or foam. Aluminum legs tend to be hollow. Polypropylene are usually hollow but are not normally used . Alignment is carried out first and then the alignment jig is removed and the shank is built up. The process of removing the alignment device is called transfer. The relationship between foot and socket must be retained.

Indication :-

- Good for almost good for almost all finished BK prosthesis .for both light and heavy work

Advantages :-

- Strength. Very strong structure.
- More strong than Endo skeletal system.
- Can be fabricated for light or heavy work.
- Durability and Cheep generally less expensive than Endo skeletal system.
- Easy to clean and to keep clean..
- Easy to make water proof.
- Very strong Cosmetic.

- And can be set up to suit the level of activity

.

B. <u>Endo skeletal Shank :-</u> Endo skeletal systems are usually called modular system. It consist of a tube metal connection to the socket from top side and to the foot from the lower side. All stress pass down this tube and not through the cosmetic covers. Cosmetic shape is given by the addition of soft cover.

Alignment devices are part of the structure of the leg. After alignment is completer the devices locked so the alignment cannot change.

<u>4-2 There are tow major types of alignment device</u>:-

1. **Tilt / Shift :-** in this type the alignment can be changed as a tilt or shift from the one alignment device.
2. **Tilt / Tilt :-** in this system the alignment can only be changed using a series of screws to change the angle of the socket .

5-1 Prosthetic Feet:-

The prosthetic foot must be cosmetic and functional. It must behave as much like the real foot as possible. There are many designs of foot. They can be simple in action or very complicated.

A. **S.A.C.H Foot :-** the most common foot in the world. It function well is light weight and is very strong. It has moving parts and long lasting. **S.A.C.H** is abbreviated of (**S**olid **A**nkle **C**ushioned **H**eel). It is consists of wooden keel , a resilient covering material around the keel , a short length of belting passing underneath the keel and extending forward into the toe section , a bolt that attaches the foot to the shank, and a compressible " cushion heel " .the basic **S.A.C.H** foot provides motion due to selective compression of the material of which the foot is constructed , rather than by any articulated movement of its segments. The cushion heel is available with different degrees of compressibility which are selected on the basis of amputation level , body weight and ability to control the prosthesis. Because this foot – ankle assembly has no movable articulation, the junction line between the foot and the shank is minimal. A **S.A.C.H** foot is also available with an external keel. The wider keel reduces the small amount of mediolateral movement that is obtained with the internal keel. and may be considered for a patient who required additional stability. The shock absorption at heel strike is carried out by the heel cushion which compresses and softens the action. At push off the foot's springy toe section gives the push off action .as shown in fig. 1

5-2F oot Action :-

a) Planter flexion is achieved by compression of heel wedge.
b) Dorsi flexion is not permitted except at spring toe section.
c) Medial / Lateral forces are absorbed by the soft sole.

5-3 Advantages of S.A.C.H Foot:-

1st. Light weight.

2nd. Very strong.

3rd. No movement parts (quite).

4th. Little maintenance.

5th. Good shock absorption.

5-4 Disadvantages of S.A.C.H Foot:-

1) Limited possibilities for adjustment of planter / dorsi flexion.
2) The heel cushion may loose elasticity with time.
3) The rubber heel cushion may corrode with tine.

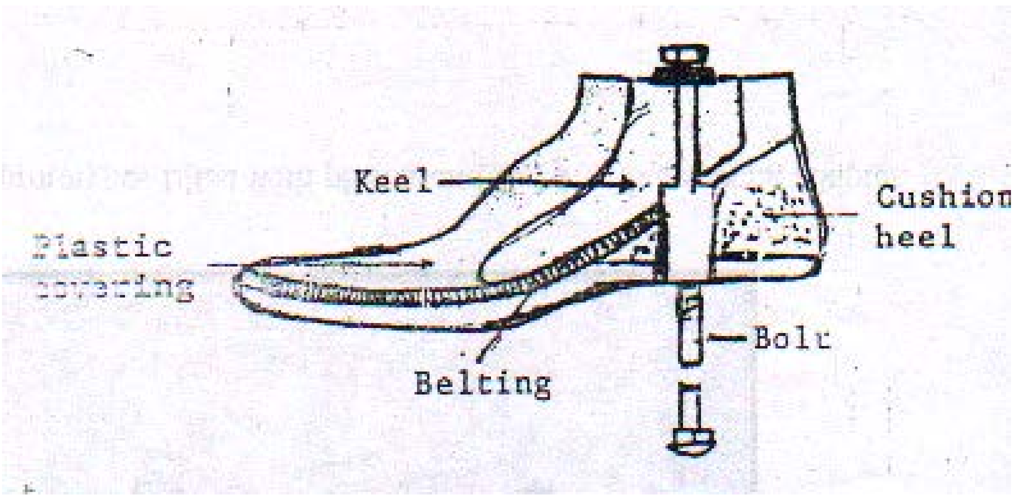
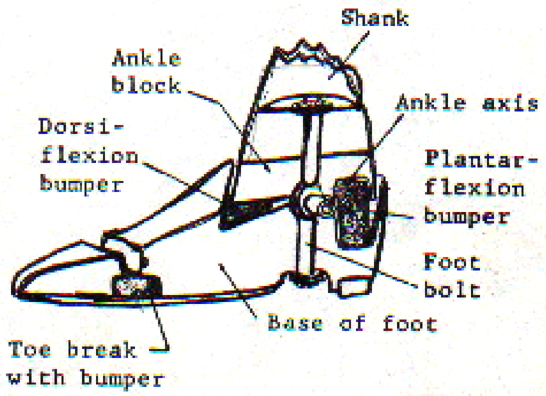
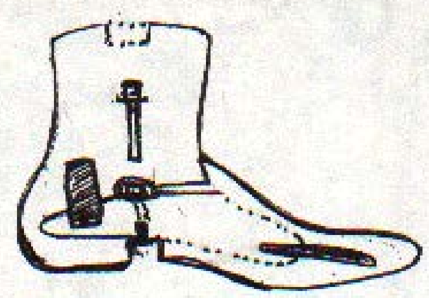


Fig 1 :- A **S.A.C.H** foot with internal keel

B. **Single Axis Foot:-** the base of the foot is connected to the ankle block by a bolt. The transverse ankle axis permits the foot to go into planter flexion and dorsial flexion. All motion is around one axis. As the foot goes in to planter flexion. A planter flexion bumper (a small cylinder of rubber behind the ankle axis) is compressed, offering resistance to the motion. In this respect the action of the dorsi flexors of the foot in the intact limb. The planter – flexion bumper permits about **15 -17** degree. In opposite direction the motion is resisted by the dorsialflexion bumper, which is positioned in front of the ankle axis. The bumpers made of rubber, felt or plastic. The range of dorsiflexion of the prosthetic foot does not exceed **5** degree since the toe section of the foot must bend during the push –off phase of walking and return to neural position , this action is achieved by means of a toe break with a rubber toe bumper as illustrated in fig.2 or by means of flexible toe section as illustrated in fig. 3



Single-Axis Foot-Ankle Assembly
With Toe Break
Figure 2



Single-Axis Foot-Ankle Assembly
With Flexible Toe
Figure 3

5-5Advantages of Single Axis Foot:-

a. Increased knee stability because of the planter flexion.
b. The compressibility of bumpers can changed.
c. Better sensory feed back.

5-6 Disadvantages of Single Axis Foot:-

a) Need high maintenance.
b) Heavy weight as compared with S.A.C.H foot.
c) Less cosmetic.
d) And noisy

C. **Multiple – Axis Foot Ankle Assembly :-** It is permits movement in any direction such as :- planter flexion, dorsiflexion, invertion,eversion and rotation around vertical axis. In this type the lower end of the ankle block has curved rocker insert that rests on rubber rocker block. The curved surface permits the foot to rotate on transverse axis of the ankle joint, so that it can go into planter flexion and slight dorsiflexion. The transverse axis of the ankle joint is positioned in flexible joint holder. The flexibility of this holder permits mediolateral motion and slight rotation in horizontal plane to take place. as shown in fig. 4.

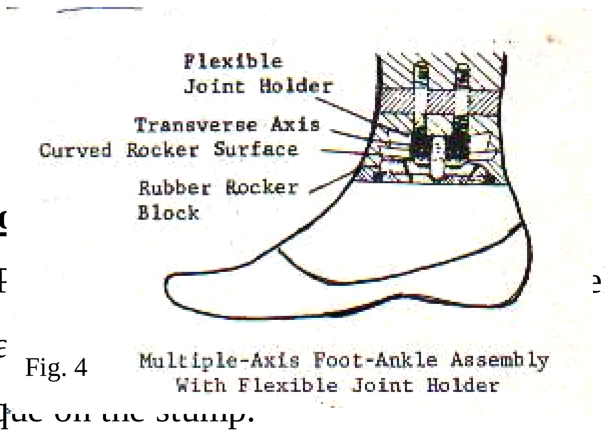


Fig. 4

5-7 Advantages o

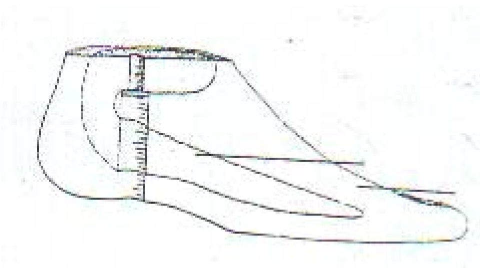
1. Allows A- F ... elp walking on uneven groa
2. Reduce torque on the stump.
3. Adjust easily.

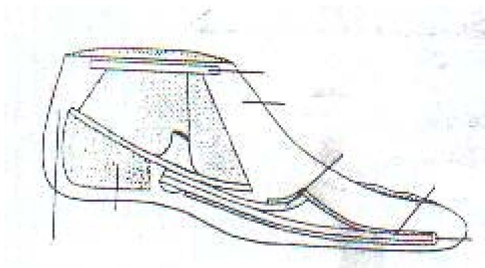
5-8 **Disadvantages of Single Axis Foot:-**

1) Increased weight.
2) Need more maintenance.
3) Poor cosmetic.
4) May provide less stability on smooth surface.

D. **Energy Foot:-** this is designed for the amputee who is able to run or walk very quickly. In the running the load on the foot is increased three times. The foot are very hard and do not perform well during normal walking.

This foot have a very strong heel spring to absorb the high load of running and a very strong toe spring to give the high impetus required in push off. They are very successful foot but are very expensive and unnecessary for normal day to day use. As shown in fig. 5





5-9 Advantages of Energy Foot:-

1. Stores an reduce energy.
2. Provides a gait pattern.
3. Provides a degree of motion similar to multi axis foot.
4. A flexible keel may ease walking on stairs and uneven ground.
5. It is available in water proof materials.

5-10 Disadvantages of Energy Foot:-

1. Provided less stability than other foot.

2. Heel cushion may be too soft for some patient.
3. The component may separated or tearing.
4. It is heavier than S.A.C.H Foot.

5-11 Training

Although the below-knee and Syme's amputee have normal knee function training in their use is necessary if optimum gait and comfort are to be obtained. Early training is provided by the prosthetist during fitting trials. Physical therapists usually provide the additional training as required.
The new prosthesis should be worn initially for short periods and wearing time increased each day depending upon individual situations.

One of the greatest problems in obtaining good performance and maximum comfort is caused by over weight of the amputee. Fluctuations in body weight are reflected in the stump where changes in volume result in poor fit, discomfort, and consequently poor performance. A reasonable exercise program and a sensible diet are important factors in the health and well being of everyone, but even more so in the case of amputees. Slight reduction in size of the stump can be accommodated by adjustments to the socket, but the prosthetist can do little about expanding the size of a socket and almost any increase in size of the stump means a new prosthesis.

5-12 Care of the Stump

The stump must be washed daily to avoid irritations and infection. Mild soap and warm water are recommended. The interior of plastic sockets also must be kept clean by washing daily with warm water and a mild soap. Use of detergents should be avoided at all times. Some amputees have found a hair dryer to be useful in drying the stump and preparing the socket for donning. Prosthetic socks must be applied carefully to avoid wrinkles, and should be replaced daily with newly laundered ones; more often in warm, humid weather. They should be washed in warm water with a mild soap. Manufacturers recommend that socks be rotated on at least a three- or four-day schedule to allow the fibers to retain their original position. Reductions in the size of the stump can be accommodated by adding one or more prosthetic socks. Prosthetic socks are woven especially for their intended use and are available in three thicknesses and a variety of sizes. The thicknesses generally available are designated 3-ply, 5-ply, and 6-ply. With this combination, various thicknesses can be obtained as follows:

One 3-ply = 3 plies
One 5-ply = 5 plies
Two 3-ply = 6 plies;
One 3-ply + one 5-ply = 8 plies

One 6-ply sock can be used instead of two 3-ply socks.

Some amputees have found that use of a one-ply cotton filler sock provides a satisfactory way to obtain a still finer adjustment in thickness. If the amputee has trouble in obtaining comfort by a combination of prosthetic socks, he should consult his prosthetist immediately. Frequent adjustments are often required in the first year. When the prosthesis does not feel comfortable during standing and walking, it should be removed and reapplied. If discomfort persists, the prosthetist should be consulted.

5-13 Maintenance of the Prosthesis

When a non-articulating foot is used, there is very little maintenance required for the below-knee prosthesis other than keeping it clean inside and out. Articulated feet generally need to be lubricated at regular intervals. The heel height of the shoe is a very important factor in the alignment of the prosthesis.

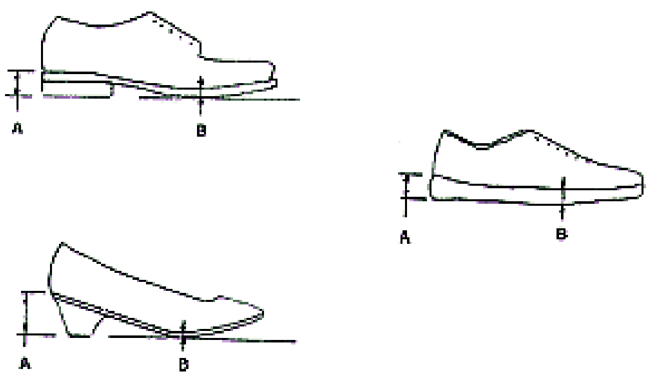
Therefore, when shoes are changed, it is important that the effective heel height be the same as on the shoes used previously. The effective heel height is obtained by subtracting the thickness of the sole (B) from the apparent heel height (A) as shown below.

For the same reason, the heels of the shoes should be replaced frequently so that wear will not result in alignment changes. Also, a badly worn shoe will increase the wear on a prosthetic foot.

Prostheses should not be worn without shoes. Not only will the temporary malalignment cause excessive stress on the stump and knee joint, but the wear on the foot will result in permanent malalignment.

Most prostheses are water-resistant but few are waterproof. If the foot becomes wet, the shoe should be removed as soon as possible to facilitate drying.

When the amputee has any doubt about the fit, alignment, or condition of the prosthesis or stump, he should consult with his prosthetist immediately.



EFFECTIVE HEEL HEIGHT = "A" - "B"

5-14 Definitions

Preparatory Prosthesis. An unfinished functional replacement for an amputated limb, fitted and aligned in accordance with sound biomechanical principles, which is worn for a limited period of time to accelerate the rehabilitation process.

Pylon. A rigid member, usually tubular, between the socket or knee unit and the foot to provide support.

Rigid Dressing. A plaster wrap over the stump, usually applied in the operating or recovery room immediately following surgery, for the purpose of controlling edema (swelling) and pain. It is preferable, but not necessary, that the rigid dressing be shaped in accordance with the basic biomechanical principles of socket design.

Early Prosthetic Fitting. A procedure in which a preparatory prosthesis is provided for the amputee immediately after removal of the sutures.

Modular Prosthesis. An artificial limb assembled from components, usually of the endoskeletal type where the supporting member, or pylon, is covered with a soft foam or other light material shaped and finished to resemble the natural limb.

Definitive, or "Permanent", Prosthesis. A replacement for a missing limb or part of a limb which meets accepted check-out standards for comfort, fit, alignment, function, appearance, and durability,

Check or Test Socket. A temporary socket, often transparent, made over the plaster model to aid in obtaining a proper fit.

6-1 Syme's and Partial Prosthesis :-

Syme's amputation it is through ankle amputate was carried by a Scottish Surgeon Mr. Jame Syme. This technique still carries his name, it is end bearing and supra malleouls suspension. The syme type prosthesis has good end weight bearing characteristic and from a prosthetic viewpoint differ in size at the distal end.

The syme's amputation is long, bulbous end and end weight bearing. Some time can not patellar weight bearing. Because of the bulbous end there is a problems in the socket fitted which need requires some kind of opening to allow entry of bulbous end and the attachment of a foot where there is inadequate ناقص room for standard foot. Before consider these problems in detail the functional requirements should be examined from biomechanical viewpoint.

6-2 Fitting and Design Symes's Socket.:-

The socket should provide weight-bearing , suspension , resistance to rotation and Anterior-Posterior and Medial –Lateral forces for stability. With a classical Syme stump , full end bearing presents no problems other than shaping the end of the socket to fit the contours of the stump. If there is some reasons is not possible for end bearing , then proximal bearing is indicated , following the Trans- Tibial prosthesis.

There are two point to bear in mined regarding this type fit. First is a proximal fit causes some restriction and in along stump this may causes circulation difficulties. Second a sym's stump will not retract from the socket like the Trans- Tibial stump when sitting , therefore , a lower posterior shelf may be indicated.

Good suspension for the prosthesis readily provided by fitting the socket snugly over the distal bulge. The only difficulty lies in providing an opening for easy entry and exit of the stump. There are various socket designs with opening made of lamination composite plastic material or use polypropylene material. The most problems on casting because of the bulbous end of stump which required good experience and more training on taking casting.

There are three type of opening window in the socket like medial , posterior and medio-postrior one. To make the opening window in the socket take a big circumference of the bulbous and a big circumference of the leg and make rectangular open the length of this rectangular depend on the distance between the circumferences and must be make good circle in corner of this rectangular to protect the socket from shear stress due to the dynamic forces.

6-3 Advantages of the Syme's stump :-

1) Higher level amputation.
2) End weight – bearing.
3) It is possible to walk with out prosthesis even with a limp.
4) Give excellent suspension with supra malleulas.
5) The opening window help the amputee to use the prosthesis easily.

6-4 Disadvantages of the Syme's stump :-

1) The cosmetic is bad because of the bulbous end of the stump.
2) It is difficult to fit a good artificial foot into the space available because of the long socket.
3) Some time the surgery can go wrong this can lead to painful stump intolerance to end bearing in this case must make a proximal bearing like Trans –Tibial prosthesis.
4) There some rotation happen during the amputee walking because of the long lever of stump making rotation moment.
5) The strength of prosthesis socket is very weak because of the opening window.
6) In the children the stump will not grow quite so fast as the sound leg that will appear shorten and give psychological problems for the amputee child.

Tolerance Area:-

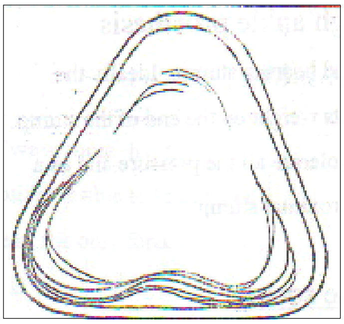
Distal end pad , PTP suspension and Tibial Flairs .

Non Tolerance Area:-

Tibia crest , Head of Fibula ,Neck of Fibula and malluls.

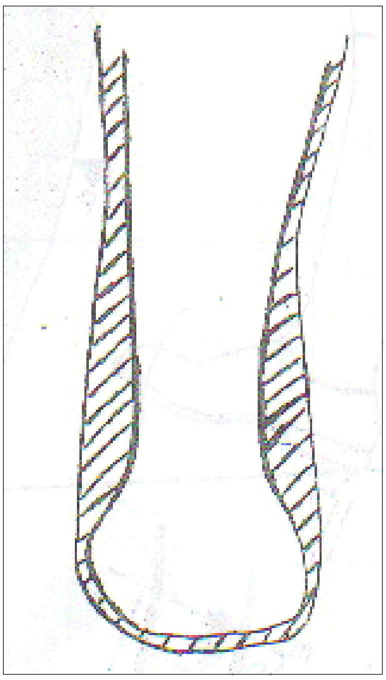
Rotation about the long axis:-

The natural triangular shape of upper end of the stump is emphasized during the casting and rectification (modeling). The triangular stump shape keyed into a triangular socket resists rotation.



Suspension:-

The wide and bulbous stump end means that is possible to hange the socket on to the end of stump. This gives good comfortable and secure suspension , the big problem then is gaining access too the socket past the narrow neck.



6-5 Ankle Disarticulation (Syme's) Measurment of Casting:-

A. Stump Measurements:-

- It is taking with patient standing.
- The patient put weight bearing on the stump.
- The pelvic must be level.

B. Diameters:-

- Maximum knee Diameter.
- Minimum Diameter above Maleoli.
- Maximum Diameter at the bulbous end of the stump.

C. Circumferences:-

- Mid patellar tendon level.
- Apex of Fibular head.
- Minimum circumference above Melioli (taken the same level as the diameter).
- Maximum circumference a bulbous end of stump(taken at same level as the diameter).
- Circumference at shaft of Tibia / Fibula .

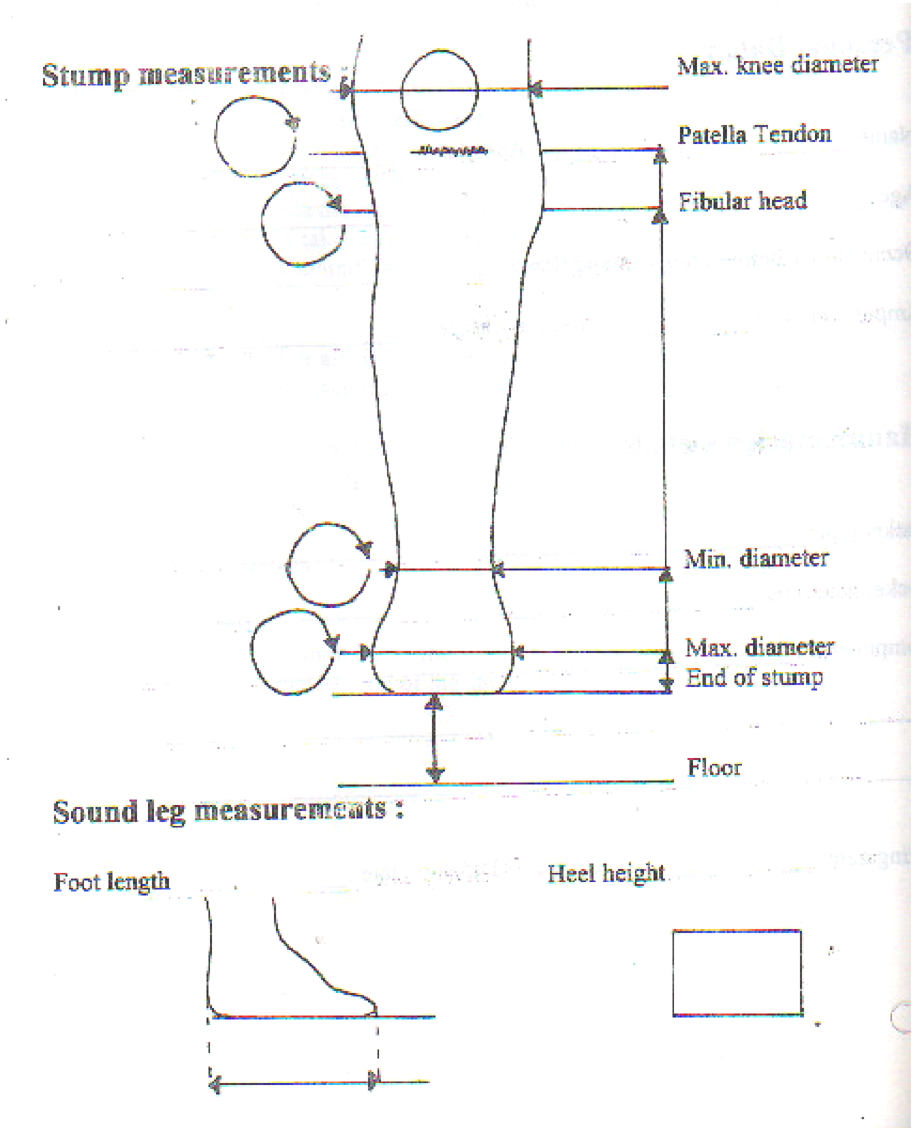
D. Distance / Length.:-

- For all circumference measurements the length from the measurement to the end of the stump is also recorded.
- High of end stump to floor with patient standing.

E. Sound leg Measurements;-

- Length of the foot.

- Heel Height of the shoe.



6-6 Ankle Disarticulation (Syme's) Casting Procedure:-

A. Aim of taken casting:-

The aim of taken a plaster cast is to ensure an accurate model of the stump which shows the stump in it's load bearing position.

B. Problems:-

1) It can be difficult to remove the cast because the shape of stump is bulbous.

2) The stump must be loaded during casting so the soft tissue on the distal end is deformed into a comfortable position.

C. Procedure Guide :-

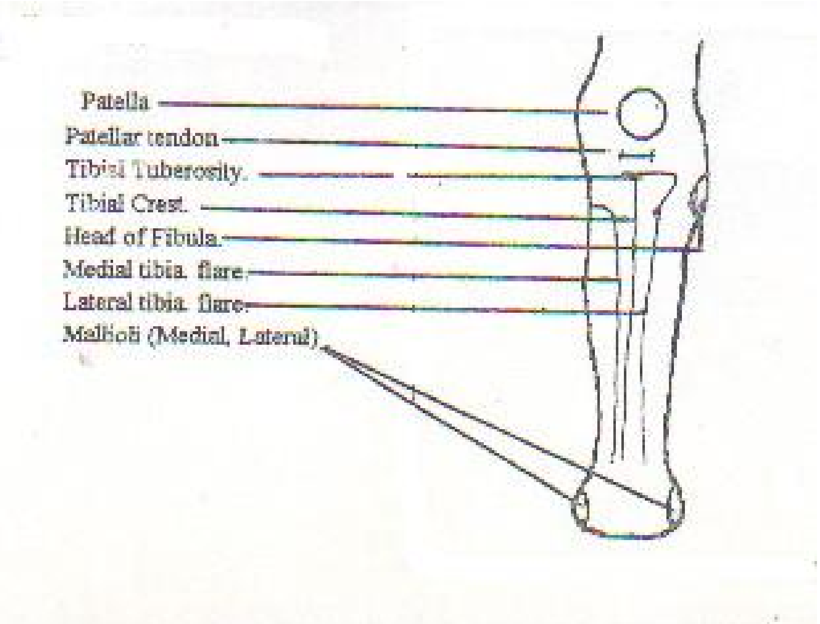
a. The patient personal details and details of manufacturing and construction should be recorded on the measure chart.

b. Details of the stump and the sound leg should also be recorded.

c. Special attention should be paid to the diameters and circumferences of the bulbous end of the stump and the narrow part of the stumpjust above the distal end.

d. To get plaster off patient must be cut the plaster. To protect the patient must be place apiece of 1 cm diameter tubing or put a strip of lead plastic under the stump sock. This is placed along the length of the stump usually on the medial side of the tibia crest.

e. The stump sock is pulled on and the stump marks made.



f. An end block is made up. This consist of a block of wood with alayerof 20mm Plastazote on the upper surface. When the patientstands on the block his pelvis should be at level.

g. The distil end of the stump is wrapped in plaster while the patient sitting, before the plaster sets then he stands and put his weight on the end of stump. The plaster must be hand molded and the P.O.P continued to the a proximal end and the tibia flares and the patella also molded by the hand and shaped to emphasis the triangular shape of stump.

h. When the plaster has set the patient sit down then the cast must be cut carefully along the lead strip, opened it enough allow the stump to be withdrawn. Care must be taken not to be damage the cast. Now the cast ready to full with plaster and make positive model.

6-7 Ankle Disarticulation (Syme's) Modeling Procedure:-

A. Purpose of modeling :-

1) To produce a model of the stump to manufacture soft socket made from Pelight material and Hard socket which is made from type of material such as composite material which is known (plastic lamination), poly propylene or either types.

2) So the model which is produced after modeling it used to make a hard socket that will off-load the pressure sensitive area of the stump and will load the pressure tolerant areas of the stump.

3) To achieve this plaster is removed from the tolerant areas and added in the sensitive areas.

4) The load areas in the Symes stumps are:-

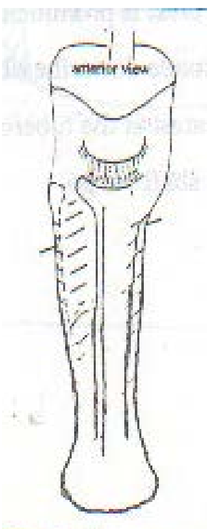
- ✪ Distal end pad.
- ✪ Tibial Flares
- ✪ Patella Tendon.

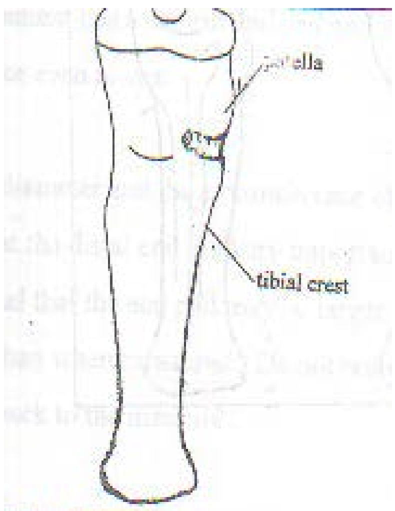
5) The pressure in tolerant area :-

- Tibial Crest and Tuberosity.
- Fibular Head.
- Neck of Fibula.
- Patella.
- Medial and Lateral malliolli Remnants.

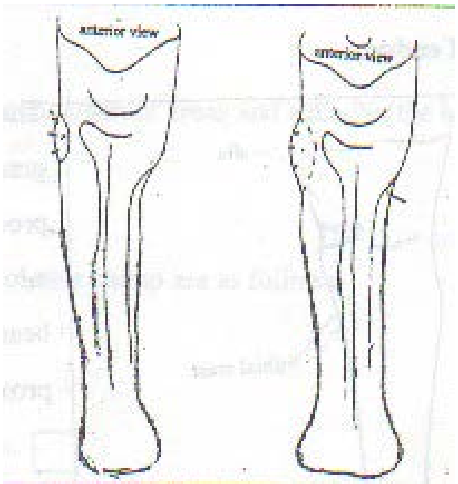
B. Rectification Procedure :-

1. **General:-** clean up obvious irregularities, Re –dress all stump marks and Check cast measures against patient measures.
2. **Medio – Lateral Diameter of the Knee:-** Measure the medial – lateral distance across the knee at the widest point and compare the measurement taken on the patient. Remove plaster until the measure is approximately half way between the patient measure and the original cast measure.
3. **Patellar –Tendon:-** The rectification of this region is generally the same as the rectification procedure for B.K. except that is a lot less severe. The must being end bearing much less load is taken proximally. A patellar tendon is made between the thumb marks in the normal way but only to a depth of about half that used in B.k.

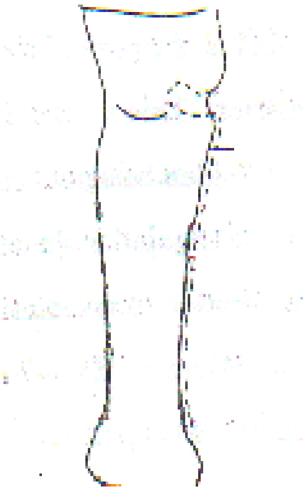




4. **Tibial Flares :-** Material is removed from the medial tibial flare and the region of the tibilis anterior. This is not carried out to produce true load bearing but more so to emphasis the triangular shape of the tibia in cross – section to resist rotation of the socket on the stump. Only from 1- 2 mm are removed at deepst point.
5. **Fibular Head :-** The fibular head and neck shouldbe bult up in the same way as in the B.K. cast. A proximately 3mm should be add at the highest point. The build up should be tapered out at the borders of the head of fibula Anterior, Posterior and Proximal. It should be continued down the shaft of the fibula for about 1 cm. to relieve the **Peroneal nerve**.

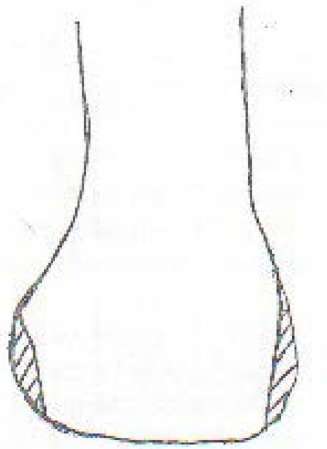


6. **Tibial Crest and Tuberosity:-** Where the tibial crest is prominent build ups of 2 – 3 mm should be made down the tibial crest. The build up should greatest at the tubersoity and reduced the further down the shaft which is going.



7. **Distal End :-** this is the major load bearing areas and requires the most care

- As the end pad is loaded it will flatten and widen .
- Some time the end pad can move during casting and can apper to be off center. It need to correct cast or need to re- cast again.
- The diameter and circumference of the cast at the distal end are very important. It is normal may be larger on the cast when measured so do not reduce the cast back to the measure.
- Small build are required on medial and lateral Mallioli sensitive areas or scars it nee to add 2-3 mm on it.



8. **Posterior Trim Line:-** It is normal to set trim line 2-3 cm below the level of mid patella tendon..

6-8 Manufacture Technique of Ankle Disarticulation (Syme's) Prostheis.

Principle:-

The socket is made in two parts. The outer socket is made of either GRP (lamination plastic) or polypropylene. While the more used now is polypropylene because it is very cheep and easily to manufactured . The hard socket is shaped as long cone. It is slightly larger at the proximal end than the distal end. Inside there is a Pelite liner name soft socket. The liner has a split running most of it's length. The patient donned the socket by pushing the stump into the liner. The liner can expand because of the split. The stump and liner are then pushed into the socket. The complicated inside shape onto the liner.

Manufacture Technique:-

1. Make up **Apilite** cone from measurements of the stump. Like technique of Trans-Tibia Prosthesis.
2. With the liner molded and capped in the normal way, carefully measure the diameter of bulbous end by using the calipers and move it up to the proximal end and mark the narrowest point on the shank that is equal to the widest part of the bulbous end this give the cylindrical out side of liner.
3. Build up the narrow area between the widest part of bulbous end and the proximal mark.

4. Apply the procedure of alignment and when the alignment finished follow any method to manufacture the hard socket either GRP lamination or by bubble drape polypropylene.
5. After finished the hard socket the model is chipped out.
6. The syme's foot is attached to the socket to the socket using static alignment.
7. the prosthesis ready for dynamic alignment.
8. The changes possible are Inversion, Eversion, Flexion, Extension and Rotation. Some time need Medial or Lateral shifting but it is affected on the cosmetic.
9. After of all alignment finished make cosmetic by cover the leg with Plastozot if the socket made from polypropylene material or by second lamination if it is made of GRP.
10. Put in mined that the alignment changes later in the process are mor difficult.

6-9 Ankle Disarticulation (Syme'sProsthetic Problem:-

When the patient comes to the prosthetist with problem, the prosthetest must make a careful assessment. The patient assessment are:-

1) Listen to the patient complaint. (شكوى)

2) Carefully observed the patient gait. To determine the alignment error could be the causes of the problem.

3) Examine the stump for signs of unwanted pressure.

4) Compare the measurements of the stump with measurements taken before , and compare the stump with socket shap.

6-9-1 Some of the Problems:-

1. **Proximal Discomfort:-**
   a. **Discomfort of Patellar tendon.**

causes	Remedy
The patellar tendon bar may be too deep, too wide, positioned in the wrong place or have wrong shape	In some cases it will be possible to change the shape of the tendon bar by heating the socket or grinding away some material. If this is not possible then must make anew socket.

b. Discomfort at the Fibula Head.

causes	Remedy
1. In some instances the socket relief for the head of fibula, causing discomfort. 2. Just posterior – distal to the fibular head runs the common personal nerve, pressure on this nerve will causes pain.	a. It may be possible to heat the socket and change the shape or to grind some material away from the inside of the socket . b. Pressure on the nerve can also cause what is called refereed pain. The patient will complain about pain at the distal part of the stump, but the source of the problem lies proximally with pressure on the common personal or on a neuroma.

c. Discomfort on the Popliteal area:-

causes	Remedy
1. The patient may experience that the top of the socket is	a) This may be corrected by adding some material to the Popliteal area.

too loses. 2. the Popliteal area is too high	b) By heating this area and compressed it a little. a. The brim may be lowered to better allow for the Hamstring Tendons. b. Or the flat of the brim may be made mor generous.

2. Distal Discomfort :-

a) Discomfort Over Anterior Aspect of Tibia:-

causes	Remedy
If the patient complains about pain at the anterior aspect of the stump, it could be because there is to little relief for the bone over this area.	To correct this some material is ground away in side this socket . Or a new socket should be made.

b) Discomfort at the edges of the distal end:-

causes	Remedy
In the case where the casting of the patient has been don with out weight bearing. In some cases this build up is too small and the patient feels pressure on the sides of the stump.	A general relief is needed around the edge of the distal end of stump. Some material can be ground a way from the inside on the socket . Or anew socket has to be made.

c) Discomfort Under the Distal End of the Stump:-

causes	Remedy
Some patients can not tolerate total weight bearing at the end of the stump. relief can be provided by adding	Relief can be provided by adding material to the general proximal weight bearing. (Note :-adding material is relatively easily done in the liner socket but it is more difficult in a hard socket.)
In some cases the patient has developed a pressure point or a bone spur under the end of stump.	The point must be accurately located and very localized relief must be made.

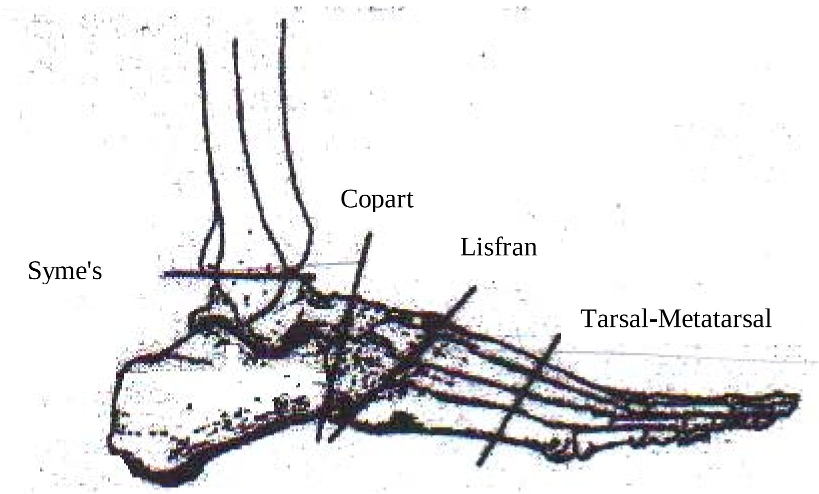
d) Discomfort Over Trimmed Maleolies:-

causes	Remedy
1. The patient feels pain and pressure on the maleolies . 2. it caused by general shrinkage of the stump causing a loss of suspension so that the prosthesis in sliding distally on the stump.	a. Make grinding and relief some of material away from inside a socket. Or made new one. b. Adding some material to the area along the shaft of tibia and fibula. Otherwise new socket made.

6-10 Partial Foot Amputation and Prosthesis

Classical Amputations Lines :-

1. Long Sharp.:- All phalanges and the distal ends of the metatarsals
2. Short Sharp:- Half of metatarsal
3. Lisfranc's :- Include complete removal of the metatarsal also the base.
4. Bone Jaeger :- Disarticulation between the navicular and os ocubideum.
5. Chopart :-only talus and calcaneus left. It is widely type known amputation.
6. Pirogroof :- the tauls removed and the calcaneus reshaped in the fork of tibia and fibula. Some time the prsthesitst make mistake by consider it syme's amputation. So it need to X- Ray film to decided the type of amputation.



6-11Type of Partial Prosthesis:-

There are three type of partial prosthesis as following;-

1) Prosthesis made from plastic material either GRP lamination or polypropylene socket and connected it with rubber foot .

2) Prosthetic made from plastic and lather together and connected by the rubber foot or lather foot.
3) Prosthetic made from lather all of shank and foot. Which is made with a special technique.

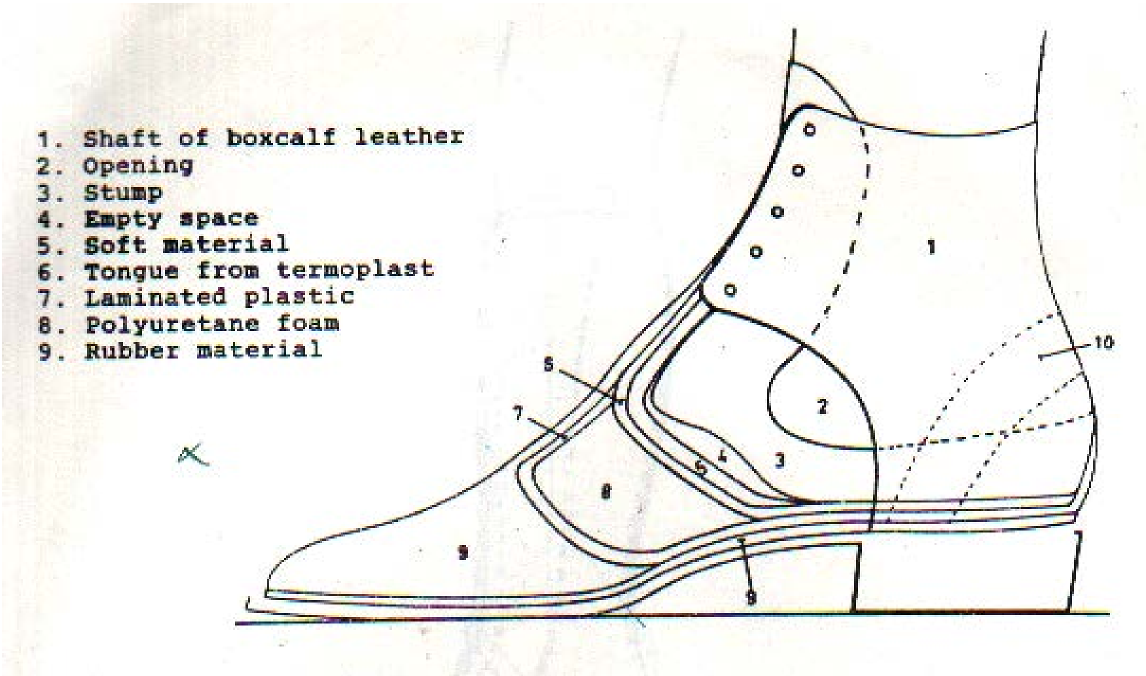
The type of prosthesis depended on the type of the amputation but the height of the shaft of the shank is depended on the type of the ankle joint movement. There are three type of ankle joint movement such as following:-

A. Free ankle joint movement can say normal movement with normal degree of planter flexion and normal degree with dorsal flexion.
B. Limited ankle joint movement may be there is planter flexion and absent dorsal flexion or opposite.
C. No movement I ankle joint can say fixed ankle joint.

From this classification of ankle movement the prosthetstest decided the type of the material used to manufacture the prosthesis and the height of the prosthesis.

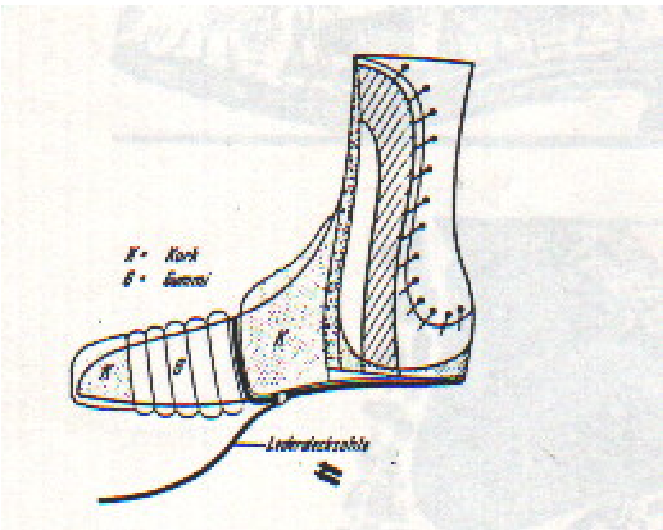
6-12 Type of material of prosthesis and the height of prosthesis due to the movement of ankle joint :-

1) For the free ankle joint movement, the prosthesis made from lather with short shaft like a boot .

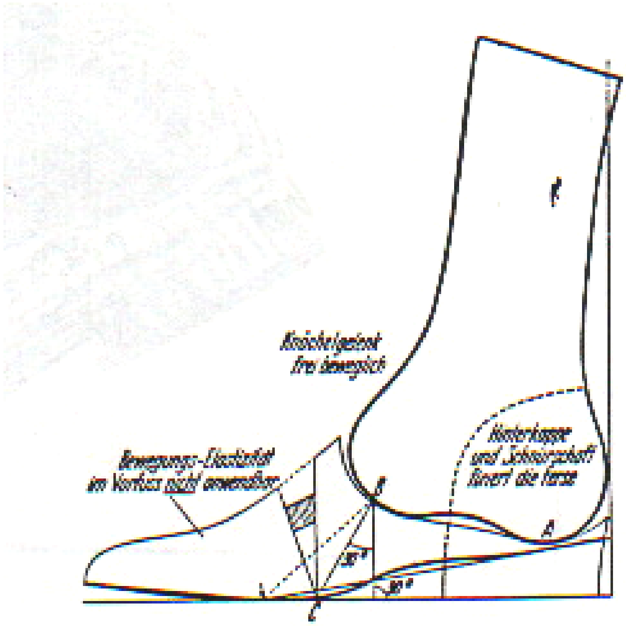


2) For the limited ankle joint , the prosthesis is made from plastic material such as GRP lamination or Polypropylene and lather and the height of the shaft depend on the planter flexion movement or dorsal flexion movement.

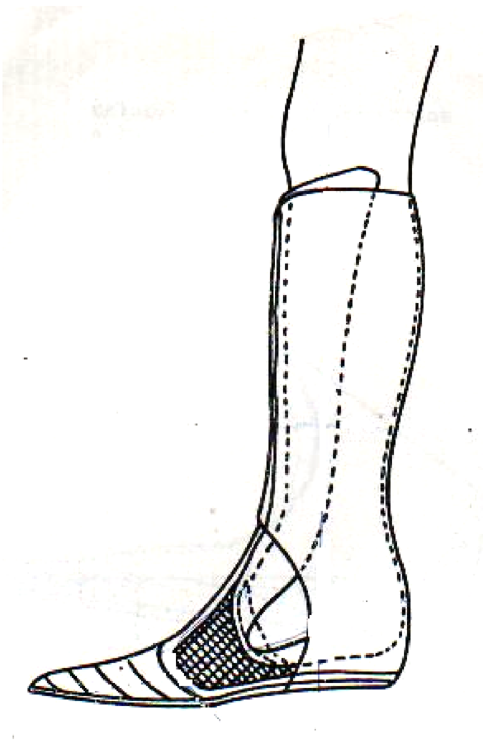
a.If the patient can move his ankle joint planter flexion and the dorsal flexion absent the shaft is short.



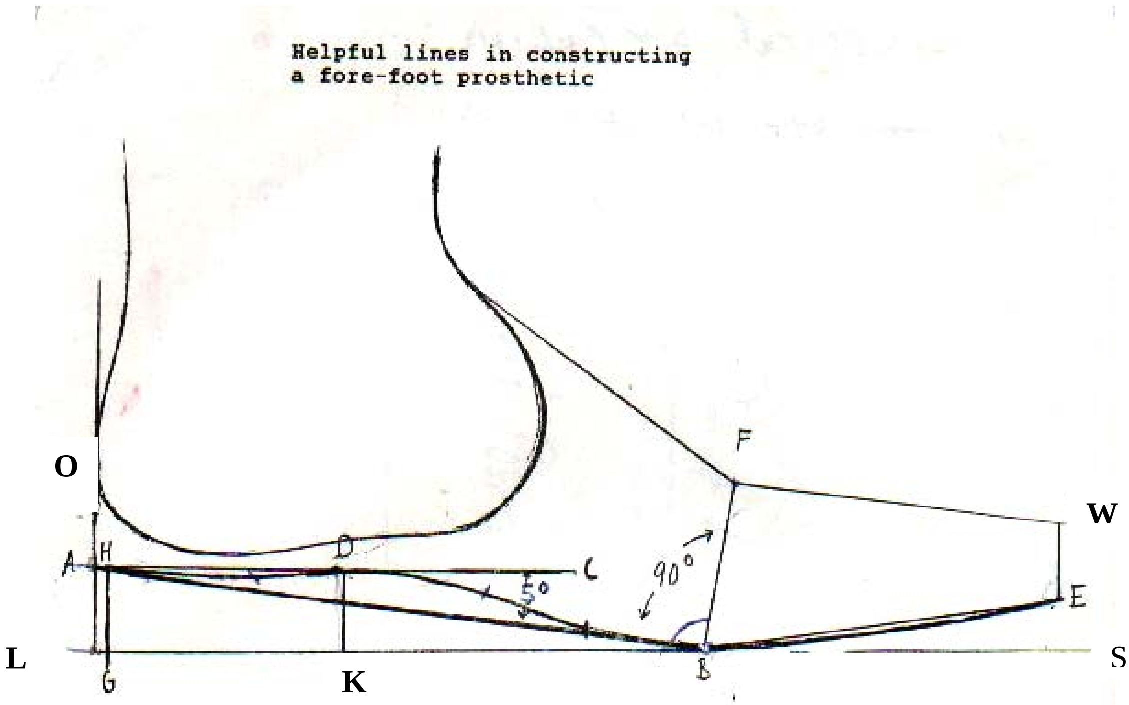
b. If the patient can move his ankle joint dorsal flexion but the planter flexion is absent the shaft is medium long.



3) If the patient can not move his ankle joint is fixed , the prosthesis is made from plastic material with height shaft.



6-13Constructing afore – foot prosthetic:-



A –B 2 /3 of the length of the sound leg foot.

B – E 1 / 3 of length of the sound leg foot.

B – F ballen line is always 90 degree with A- B line.

A –C make 5 degree with A – B line.

The distance from a to H equal 5 mm

O – L = 35 mm

A – L = 20 mm

a. Make tracing for the profile of the socket on the paper to give the same shape of the stump.
b. Draw the straight line L-G –K- B- S.
c. Draw the vertical line L- A- O perpendicular with line L- G – K- B – S from point L this line will tangent the socket shape at point O which is fare of the point L 35 mm .
d. Draw line A-H-C parallel to line L-G –K- B- S.

e. Draw the line A-B with angle 5 degree.
f. Divided the distance L-B in two part , from mid point K draw vertical line cutting the line A-H-C at point D.
g. From point F draw line tangent the profile shape of the socket
h. From point F draw line parallel to the line B-S.
i. From point B with 5 degree draw line B-F with length of distance 1/3 of the length of the sound foot. And from F draw vertical line cutting the line which is drawing from F at point W.
j. Curved line between H –D-B –E could be draw this line represents the bottom of the prosthesis foot.
k. The profile of the shape of the end foot.

6-14 **<u>Casting of Partial Foot :-</u>**

The plaster cast is always wrapped towards varus. Frequently calcanus is in varus position , and it is important that wrapping develops best possible alignment. At the same time the point of **Achilleus Tendon** attachment is pressed in the planter direction. The distal part of the foot is pushed dorsally to an angle less than 90 degree. (ideally from 70 -80) degree.

After wrapping the foot is loaded , heel on the floor and the front part in dorsalextenstion. Put on hand under the distal part and push the heel in the planter direction on the floor with other hand. Then mark on the plaster :-

- **The gait – line.**
- **The load line.**
- **The vertical line.**

<u>6-14-1 The gait – line:-</u> is important to make sure that:-

1. the toe – off rocker is aligned to the direction of the step.
2. the distance is matched to the other foot.
3. the direction of the front part matches the other foot.

<u>6-14-2 The load line:-</u> indicate the following:-

1. the alignment of the upper shank.

2. the angle during casting.
3. proper alignment of foot and knee.

6-14-3 The vertical line:- indicates the following :-

1. alignment of the heel in relation to the calf.
2. the alignment of the upper shank with foot.
3. the relation between tauls – calcaneus and the tibial and fibula tips.
4. the alignment of the lateral mallieol versus the calf.

Gait analysis

7-1 Gait :- is defined as the manner or style of walking.

7-2 A full gait cycle:- is defined as the time interval between two successive occurrences of one of the repetitive events of walking.

7-3 Stance Phase:

The time from initial contact until the toes leaves the floor at pre-swing. Note that initial contact is made with the heel followed by instantaneous plantar flexion which lowers the rest of the foot to achieve foot flat position. As the opposite leg advances over the stationary foot, ankle dorsiflexion results. When the ankle reaches maximum dorsiflexion the heel begins to rise until the toes are rolling off the floor.

Note that the weight loading period corresponds with the weight unloading period of the trailing leg. While one foot accepts the body weight, the other foot is rolling off the floor.

Notice how the body is lowered onto the flexing foreleg during weight transference and how it rises in an arc over the supporting leg during single leg stance.

7-4 Swing Phase:

The time from when the big toe leaves the floor until the heel makes floor contact. Swing phase corresponds with the period of single leg stance on the contra lateral leg. Note that while the stance leg extends as the body advances over it, the swinging leg flexes at hip and knee in order to ensure floor clearance. The knee reaches its maximum extension just before initial contact, at which time the knee flexes slightly to allow for shock absorption.

7-5 The gait cycle comprises 7 major components, as follows:

1. **Initial contact :-** Initial contact, frequently called heel strike, is the first component of the gait cycle. On heel contact, the major role of the lower extremity is to absorb the impact forces created when the foot strikes the ground the ankle as the foot moves from the heel to the forefoot, allow the absorption of the forces. The ankle is usually kept in the neutral position on initial contact in preparation for the next phase

2. **Loading response :-** The loading response is the double support period between the components' initial contact and opposite toe-off. The foot is lowered to the ground by means of plantarflexion of the ankle, which is simultaneously resisted by dorsiflexion produced by the tibialis anterior.
3. **Opposite toe-off** :-After the loading response occurs, opposite toe-off is the next component of the gait cycle. It is the beginning of midstance and the first period of single support. The forefoot impacts the ground at about the same time opposite toe-off occurs. The hips move steadily through extension with power, while the knee generates an external flexor movement. The quadriceps muscles eccentrically contract, absorbing energy and allowing the knee to act like a spring (prohibiting the vertical force from rising too rapidly). The direction of the ankles shifts from plantarflexion to dorsiflexion when the tibia passes over the stationary foot.
4. **Midstance** :- Midstance is the period between opposite toe-off and heel rise. It signifies the moment when the swing-phase leg passes the stance-phase leg. During the period, the hip begins to lose its extensor movement with a decline in contraction of the gluteus maximus and hamstrings. The knee shifts its motion from flexion to extension and at the same time generates power. As the tibia moves forward over the ankle due to the inertia created by the trunk, it undergoes external rotation concomitant with forefoot supination. The ankle continues to shift from plantarflexion to dorsiflexion with the triceps surae muscle (gastrocsoleus complex) contracting eccentrically. The speed at which the center of mass of the body moves over the supporting stance-phase limb is regulated by the power created during plantarflexion of the ankle.

5. **Heel Rise:-** Heel rise is the next component of the gait cycle. As the name describes, the heel begins to lift from the walking surface. A progressive internal flexor moment is created at the hip, while an internal flexor knee moment is initiated when the quadriceps muscles stop contracting before heel rise. The knee action is thought to occur because the upper body moves faster that the tibia and because the triceps surae retards the forward motion of the tibia while the femur steadily moves forward. These motions create an external extensor moment opposed by an internal flexor moment at the knee. The ankle has an internal dorsiflexor moment as the soleus and the gastrocnemius begin to progressively contract.
6. **Opposite initial contact**Opposite initial contact signifies the start of preswing. With the start of opposite initial contact, the hip and knee begin to flex while the ankle is plantarflexing. Of note, the body now pivots on the forefoot instead of the ankle. This is the component of the gait cycle that creates the most power; the triceps surae and other secondary ankle plantarflexors create a corresponding internal plantarflexor moment in response to the external dorsiflexor moment. These muscles use an eccentric contraction.Consequently, the triceps surae is used to impede the body's momentum instead of launching it forward. This allows favorable ankle stabilization and a decline in the amount of fall by the body's center of gravity; therefore, the component of heel rise mentioned previously would be more appropriately named roll-off. In addition, the adductor longus muscle acts as the primary hip flexor in this phase, and the rectus femoris muscle contracts eccentrically to stabilize knee flexion. All of these actions assist with forward acceleration of the leg into the swing phase
7. .**Toe-off**The next component, toe-off, marks the end of the stance phase and the beginning of the swing phase. Muscle contraction changes from

eccentric in stance phase to concentric in swing phase. Toe-off occurs at about the 60% point of the gait cycle. An internal flexor moment occurs at the hip secondary to inertial forces and contraction of the adductor longus and iliopsoas muscles. The rectus femoris muscle contracts to prevent excessive knee flexion, and the internal plantarflexion moment loses power at the ankle as the toe leaves the ground.

7-8 Stride length:- The distance covered during the starting point in the gait cycle, starting with initial contact . For example, if the left foot is the starting point or reference, the cycle continues until the left foot makes initial contact again.

7-9 A step length:- is one half the stride length.

The components of the gait cycle can be divided into 2 phases:

(1) the stance phase:- when the foot is making contact with the ground. It covers the first 4 components of the gait cycle.
(2) the swing phase. when the foot is moving forward through the air and consists of the other 3 components of the gait cycle.

The gait cycle begins when one foot contacts the ground and ends when that foot contacts the ground again. Thus, each cycle begins at initial contact with a stance phase and proceeds through a swing phase until the cycle ends with the limb's next initial contact. Stance phase accounts for approximately 60 percent, and swing phase for approximately 40 percent, of a single gait cycle.

Each gait cycle includes two periods when both feet are on the ground. The first period of double limb support begins at initial contact, and lasts for the first 10 to 12 percent of the cycle. The second period of double limb support occurs in the final 10 to 12 percent of stance phase. As the

stance limb prepares to leave the ground, the opposite limb contacts the ground and accepts the body's weight. The two periods of double limb support account for 20 to 24 percent of the gait cycle's total duration.

Stance phase of gait is divided into four periods: loading response, midstance, terminal stance, and preswing. Swing phase is divided into three periods: initial swing, midswing, and terminal swing. The beginning and and ending of each period are defined by specific events.

7-10 STANCE PHASE:

1. **Loading response begins with initial contact, the instant the foot contacts the ground. (Normally, the heel contacts the ground first. In patients who demonstrate pathological gait patterns, the entire foot or the toes contact the ground initially.) Loading response ends with contralateral toe off, when the opposite extremity leaves the ground. Thus, loading response corresponds to the gait cycle's first period of double limb support.**
2. **Midstance begins with contralateral toe off and ends when the center of gravity is directly over the reference foot. (Note that this phase, and early terminal stance, the phase discussed next, are the only times in the gait cycle when the body's center of gravity truly lies over the base of support.)**
3. **Terminal stance begins when the center of gravity is over the supporting foot and ends when the contralateral foot contacts the ground. During terminal stance, around 35 percent of the gait cycle, the heel rises from the ground.**
4. **Preswing begins at contralateral initial contact and ends at toe off, at around 60 percent of the gait cycle. Thus, preswing corresponds to the gait cycle's second period of double limb support.**

7-11 SWING PHASE

1. **<u>Initial swing</u> begins at <u>toe off</u> and continues until <u>maximum knee flexion</u> (60 degrees) occurs.**
2. **<u>Midswing</u> is the period from <u>maximum knee flexion</u> until the tibia is vertical or perpendicular to the ground.**
3. **<u>Terminal swing</u> begins where the tibia is vertical and ends at initial contact.**

7-12 GAIT ANALYSIS TERMS

To understand instrumented gait analysis and the impact it has had on medicine one must have a rudimentary understanding of human gait. Therapists, doctors and other healthcare professionals look at certain aspects of gait to determine where a problem might lie and what needs to be done about it. What follows is a brief description of what is evaluated during gait analysis.

7-13 Kinematics

The study of motion. In gait analysis this includes how far the involved joints are moving and in what planes. For example the knee normally moves from approximately –5 degrees of extension to 40 degrees of flexion during a normal swing thru phase. The amount of movement, the speed of the movement and symmetry of the movement can be evaluated.

Ground Reaction Forces

This is the sum of all the forces of the body segments while the foot is in contact with the ground. This information lets clinicians see what part of the foot is bearing the brunt of the weight as it moves thru the gait cycle.

7-13Temporal Parameters

1) Step Time is the time elapsed from the first contact of one foot to the first contact of the opposite foot.

2) Gait Cycle is the elapsed time between the first contact of two consecutive footfalls of the same foot.

3) Ambulation Time is the time elapsed between the first contacts of the first and the last footfalls.

4) Velocity is obtained after dividing the Distance by the Ambulation time.

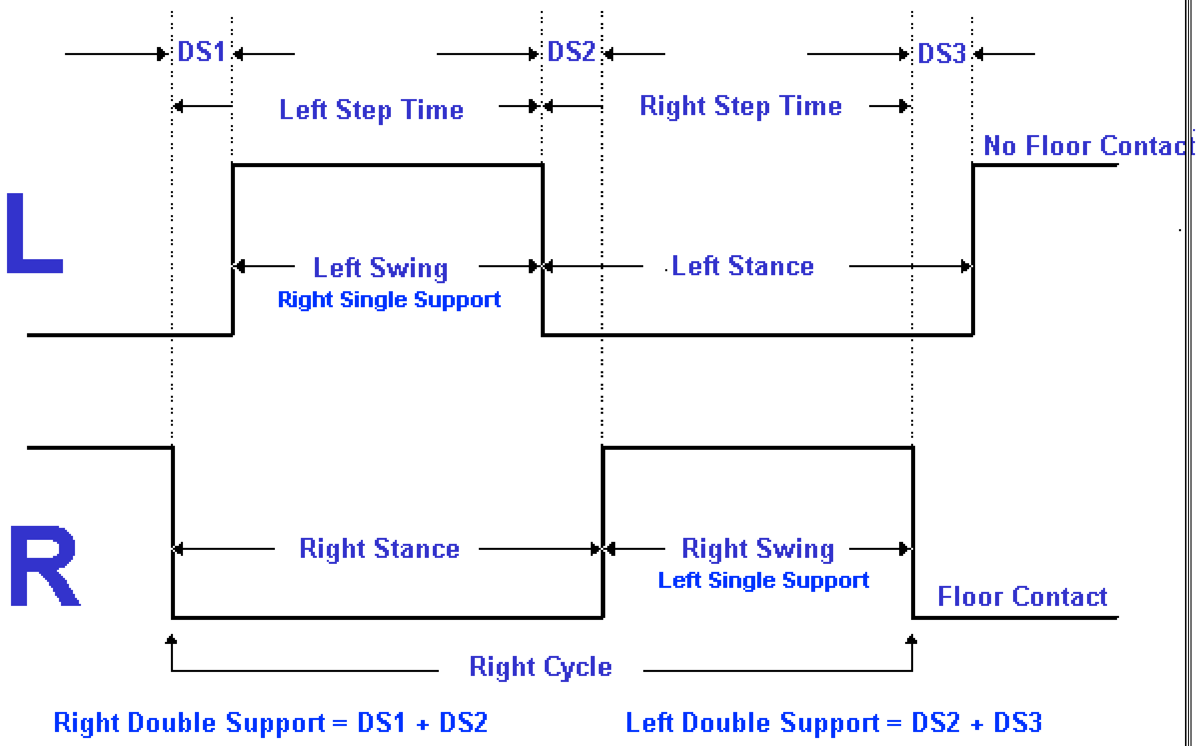
5) Mean Normalized Velocity is obtained after dividing the Velocity by the Average Leg Length and it is expressed in leg length per second (LL/sec). The average Leg Length is computed (left leg length + right leg length)/2.

6) Single Support time is the time elapsed between the Last Contact of the current footfall to the First Contact of the next footfall of the same foot. This is equal to the Swing Time of the opposite foot.

7) Double Support is the time elapsed between First Contact of the current footfall and the Last Contact of the previous footfall, added to the time elapsed between the Last Contact of the current footfall and the First Contact of the next footfall.

8) Stance Time is the time elapsed between the First Contact and the Last Contact of two consecutive footfalls on the same foot. It is also presented as a percentage of the Gait Cycle of the same foot.

9) Swing Time is the time elapsed between the Last Contact of the current footfall to the First Contact of the next footfall on the same foot. It is also presented as a percentage of the Gait Cycle of the same foot. The Swing Time is equal to the Single Support time of the opposite foot.



7-14 Spatial Parameters

1) Step Length is measured on the horizontal axis of the walkway from the heel point of the current footfall to the heel point of the previous footfall on the opposite foot. The step length can be a negative value if the patient fails to bring the landing foot heel point forward of the stationary foot heel point.

2) Stride Length is measured on the line of progression between the heel points of two consecutive footfalls of the same foot (left to left, right to right).

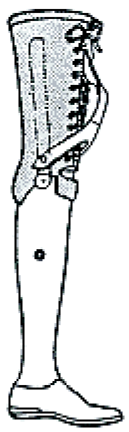
3) Step/Extremity Ratio is Step Length divided by the Leg Length of the same leg.

4) Toe In / Toe Out is the angle between the line of progression and the line connecting the heel point to the forward point of the footfall. This angle is reported positive for toe out and negative for toe in.

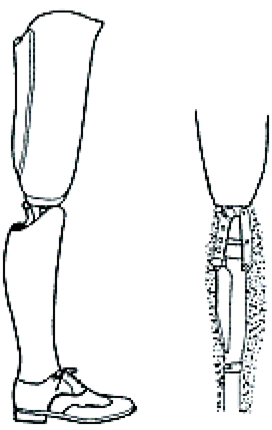
5) H-H Base of Support is the perpendicular distance from heel point of one footfall to the line of progression of the opposite foot.

8-1 Knee-Disarticulation Prostheses

The knee-disarticulation prosthesis is very similar to the above-knee prosthesis, except for the lower part of the socket and the knee mechanism. Before the introduction of the present day polycentric knee units, sockets for the prosthesis were usually made of leather and metal hinges were used to attach the socket to the shin. This type of prosthesis is still preferred by a few preferred even though it is bulky and control of the leg during the swing phase is difficult. However, most prefer one of the polycentric designs where the knee mechanism can be installed within the shin due to its special design. The major objection to the polycentric units is that the knee protrudes slightly beyond the front of the shank when the amputee is sitting or kneeling. Leather sockets are held on by a lacing. Plastic sockets usually have a foam liner in the lower part for the bulbous end of the stump to slip by so as to keep the socket in place. All of the instructions given about use of the above-knee apply equally to the Knee-Disarticulation prosthesis.



Prosthesis for knee-disarticulation amputees that uses hinges on the outside if the socket.



Prosthesis for knee-disarticulation amputee that uses a four-bar polycentric knee unit.

The knee disarticulation, also known as a through-knee amputation, has been with us for nearly two centuries. The first knee disarticulation in the United States was recorded in 1824. Through-knee amputation provides a longer lever arm and improved muscle control of the limb compared with above-knee amputation. Through-knee amputation also allows use of a total end-bearing prosthesis, which avoids the ischial pressure and suspension belts required of the above-knee amputation prosthesis.

8-2 The knee disarticulation may well be the wisest choice for several distinct groups of people:

- For children, as an alternative to a thigh-level amputation, to preserve the growth plate at the end of the femur (thigh bone).
- For cancer or trauma patients when the tibia cannot be saved but the full femur remains intact and there's good soft tissue for padding.
- For people who have problems with spasticity (erratic, uncontrolled motion) or contractures, which can result from spinal cord or brain injuries. Spasticity and severe contractures can leave the person with little or no knee mobility, and the knee often becomes fixed in a bent position.
- In these cases, the knee disarticulation can offer some unique advantages over either a transtibial or transfemoral (aboveknee) amputation

8-3 **Advantages of a Knee Disarticulation**

In a knee disarticulation, the residual limb can generally tolerate some end weight bearing and provides a long mechanical lever that is controlled by strong muscles. The person retains a full-length femur, and the thigh muscles tend to be stronger because they are released at their distal (far) end, rather than transected at mid-muscle. Muscles that are cut at mid-thigh retract, become swollen, need more time to heal, and never quite regain all their strength. Farther down the leg, in the knee area, muscle blends into fascia (connecting tissue) and tendon. In a knee disarticulation, the surgeon does not cut through any muscle bellies. Instead, the surgical cuts are made in an area where the muscle blends into tendons, and these tendons hold surgical attachments far better than muscle does. Knee disarticulations have particular advantages for children who are still growing because the growth plates at both the top and bottom of the femur are preserved. Most of the femur's growth happens at the lower growth plate so the femur will not grow much more if the lower end of the bone is removed. If a young child has an amputation at mid-thigh, the residual limb will not keep pace in growth with the other limb. So, what may appear to be a long transfemoral amputation can turn out to be a short, troublesome residual limb by the time the person is an adult. If the child has a knee disarticulation, on the other hand, the femur will continue growing into adulthood. And, since the knee disarticulation occurs between bones, rather than by cutting through bone, it usually eliminates the childhood condition of painful bone overgrowth, which typically occurs after a bone is transected and new bone growth forms a spike or spur at the end of the amputation.

Intuitively, the knee disarticulation may seem functionally similar to a long transfemoral amputation. But several studies show that function with a knee disarticulation surpasses that of higher-level amputations and actually may be closer to that of a transtibial amputation when it comes to walking speed and ease of donning a prosthesis. However, additional research indicates that in cases of high-energy trauma, people with knee disarticulations may have some difficulties not seen as often with transtibial and transfemoral amputations. We'll get to these studies and particular characteristics later

8-4 And the Disadvantages

On the minus side, while the patella (kneecap) can be retained, the two bones in the lower leg, the tibia and fibula, are completely removed. Unfortunately, the loss of the lower part of the knee joint essentially eliminates all knee power. While a person with a short transtibial amputation retains the entire knee joint and some of the tibia, providing much of the power needed to push up to go from sitting to standing, someone with a knee disarticulation no longer has that knee power. The person with a knee disarticulation, however, does have the benefit of the surface of half the joint to support weight. This, it is hoped, will make it possible to comfortably take weight directly on the end of the femur, which then allows for a lower profile socket that can provide greater comfort. Like the Syme, the knee disarticulation often results in a residual limb with a bulbous end. Some people don't like its appearance. And the bulbous shape of the limb also makes it a bit more challenging for a prosthetist to craft a prosthetic socket that fits it well. Prosthetists see individuals with knee disarticulations much less often than they do people with other lower-limb amputation levels. Because many prosthetists are not as experienced at creating sockets for people with knee disarticulations as they are for people with transtibial amputations, they have to work harder to achieve a good fit. Some prosthetists may even be reluctant to make one at all because they are less confident of a successful fitting. But, as Dr. Rogers noted, the bulbous nature of the residual limb makes the socket self-suspending. Once the limb is inside, usually it's secure and the socket won't fall off.

Another problem with appearance is that one thigh segment is longer than the other. The right and left don't match anymore because several inches of extra length are needed on the amputated side for the distal padding, the socket, the connector and the prosthetic knee unit. When the person is sitting, the thigh section of the amputated leg is at least two inches longer than the other leg, and when he or she is standing, the joint center of the amputated leg is lower to the ground than the other knee is. In addition, the swinging action of the knees occurs at different levels. This looks as if it would be uncomfortable and cause major complications to the hips and back. While it seems obvious that this is a “big problem,” there's actually little or no data to support this belief. As long as the prosthesis is designed so that the total length of both legs is equal and the hips remain level, the back can be straight, and for many there is no discomfort.

Some individuals with knee disarticulations do have problems, but the problems associated with a higher-level amputation may actually be worse. The lack of documented cases in the literature where problems are directly attributed to different levels of the knee centers is notable, and this absence may indicate that the number of back and hip problems related to the difference in knee centers is far less than assumed. In fact, there are no studies showing that individuals with knee disarticulations have higher rates of back or hip troubles than people with transfemoral amputations do. Back and hip troubles would appear to be an issue with both groups.

I've had patients tell me that a higher amputation revision was recommended simply on the basis of uneven knee levels, and that's unfortunate because there is no data to prove that the difference in knee levels is detrimental. Advocates of this belief are basing their recommendation on hearsay and not evidence-based scientific study. If a knee disarticulation is revised, it must be shortened to a transfemoral amputation, which means additional issues and difficulties. The advantages of the knee disarticulation are lost when the amputation is revised up to the thigh level. When this happens, the person's residual limb can no longer support much, if any, end weightbearing. Since the end can't take much weight, the socket transfers weight to the side of the thigh and up onto the pelvis. The part of the pelvis that a person sits on is called the ischium. A transfemoral socket can be made so the ischium sits on it like a seat or so the socket goes around the ischium and contains it. Either way, the transfemoral socket usually pushes uncomfortably into the groin and buttocks, especially when the person is sitting. Unlike a transfemoral amputation, a knee disarticulation that's comfortable and has good padding can tolerate weight on the very end of the residual limb, and then the pelvis is not needed as much for weightbearing.

Socket fit is important when a person is standing, of course, but many people don't realize just how vital it is when a person is sitting. Since prosthetic devices are made for walking, we usually think about them for walking. However, we actually spend more time sitting than walking, and the socket must, therefore, also be comfortable when we are sitting. The top of the socket for a knee disarticulation prosthesis can often be made lower and softer than the socket for a transfemoral amputation. As a result, the proximal brim does not dig into the groin and the buttocks as much, and the socket can often be much more comfortable. Sometimes, this kind of socket is not initially used after knee disarticulation surgery because the area is still tender. However, about a year later, many people with a knee disarticulation can benefit from a much lower socket profile than if a transfemoral amputation had been done.

The most commonly used prosthetic knee unit for a knee disarticulation is called the 4-bar linkage knee. The 4-bar has four connectors, or pivots, working together and two bars on each side. Their alignment causes the knee center to move up higher on the prosthesis so that it's easier for the person to keep the weightbearing line in front even when the knee is bent a little. The hinges work in concert to move the pivot point higher, making the unit more stable. This type of knee unit also improves the sitting appearance of the legs and lessens buckling of the knee when the person is standing.

8-5-The Knee cap

There's no conclusive scientific evidence to say whether the kneecap should be removed or retained in a knee disarticulation. I've found through experience that there are times when it's beneficial to preserve it. The quadriceps muscles in the thigh blend into a large tendon that contains the kneecap. The part of this tendon above the kneecap is called the quadriceps tendon, and the part of the tendon below the kneecap is called the patella tendon. But it is actually just a single tendon with a bone in its middle, not two separate tendons. This odd nomenclature was “etched in stone” centuries ago and remains with us today. The kneecap is a sesmoid, or a bone that forms inside tendons that curve around bones. This wonderful piece of natural engineering prevents the tendon from rubbing directly on the bone, which would cause the tendon to fray and tear. The bone exterior with cartilage provides a smooth gliding surface. And, by pushing the tendon away from the center of the knee joint, the tendon is stronger and has more of a mechanical advantage. Retaining the kneecap protects that tendon as it goes over the bone and helps with the attachment to keep the quadriceps strong.

If there's a choice, I prefer saving the kneecap. I've had patients tell me, “I like moving my kneecap. It makes my knee feel better.” It seems to give them more of a comforting feeling, as well as a way to work the joint just a little bit. But if the kneecap is damaged by fracture, or if there's a great deal of arthritis between the kneecap and thigh bone, it might be wiser to remove the kneecap. Though I believe there are some small, but real, benefits to retaining the kneecap if it is healthy, if there's a bad fracture, cartilage damage or arthritis, addressing these problems becomes more important, and it may be worthwhile to remove the kneecap.

8-6 Function

Several studies have examined function following a knee disarticulation. Though some have shed interesting light on the different aspects of function, others have left us with more questions than answers.

A study titled Energy demands for walking in dysvascular amputees as related to the level of amputation (by M.S. Pinzur, J. Gold, D. Schwartz and N. Gross, published in the September 1992 issue of Orthopedics) looked at energy levels and self-selected walking velocity (the pace at which a person chooses to walk). The researchers looked at 25 people who had undergone amputation as a result of peripheral vascular disease (PVD) and five control patients of similar ages with PVD. Five of the study participants had mid-foot amputations, five had Syme ankle-level disarticulations, five had transtibial amputations, five had transfemoral amputations, and five had knee disarticulations. Each member of the five groups of people with limb loss and the five controls were measured for cardiac function and oxygen consumption while at rest, while at normal walking speed, and while at maximum walking speed. With the amputations higher up the leg, the researchers found that normal walking speed and cadence decreased, while oxygen consumption per meter walked increased. Also, the capacity to increase walking speed and oxygen consumption lessened. In other words, the higher the amputation level, the more effort needed to walk either short or great distances. A person with a transfemoral amputation uses more energy to walk than a person with a mid-foot amputation does. People with a knee disarticulation tend to have walking characteristics between those of people with transfemoral and transtibial amputation levels. The assumption might be that the function of those with a knee disarticulation would be closer to that of those with a long transfemoral amputation level, but, as this study shows, individuals with a knee disarticulation actually function closer to transtibial amputees than to transfemoral amputees. Why this is, we don't know.

The Lower Extremity Assessment Project (LEAP), an eight-site study coordinated through Johns Hopkins University, examined about 169 lower-limb amputations resulting from high energy trauma, including 18 knee disarticulations. The results were presented at the Orthopedic Trauma Association 2002 and 2003 annual meetings, and the principal investigators were E. MacKenzie and M. Bosse. The primary outcome measurement tool was the Sickness Impact Profile (SIP), a questionnairebased outcome tool designed for health status research. Using the SIP, researchers were surprisingly unable to measure differences between the individuals with transtibial and transfemoral amputations. Interestingly, however, the study did show that those people with knee disarticulations from trauma had worse scores on the SIP than the other amputees. Also, by seven-year follow-up, at least five individuals had surgery to revise their knee disarticulation to the transfemoral level.

During a careful review, we found that almost all of the knee disarticulation surgeries involved tissue from the zone of injury. One theory is that these individuals did not have good, comfortable, scar-free padding that would allow the advantages of end weightbearing. I am one of many investigators involved in this multicenter project, and we have begun to recommend against doing the knee disarticulation in trauma when the soft tissue around the knee shows signifi- cant damage from the injury. This is consistent with the concept that the quality of soft tissue padding is more important than the length of bone. While the LEAP study suggests that in trauma cases, the knee disarticulation is less functional than transtibial or transfemoral amputations, this study has a small number of knee disarticulation subjects with a wide variety of injury patterns. This makes it difficult to reach a final conclusion, and, clearly, more study is needed.

"So if they had it all figured out in 1940, we must certainly have it figured out now. Right?"
- Dr. Doug Smith, orthopedic surgeon, 2003

It's Better When It's Better and It's Not When It's Not

While speaking in an educational setting or when performing telephone consultations, I'm sometimes asked whether I think a knee disarticulation would be preferable to a transfemoral amputation and if it should be done in a particular circumstance. That's a tough question to answer because "it's better when it's better and it's not when it's not." What a horribly accurate summary.

What I mean by that is if the amputation site heals without tenderness and is well-padded, there's a very good chance that the person with a knee disarticulation will be better off than if a higher amputation level were chosen. But if the amputation site heals in a scarred and tender fashion, then it clearly would have been better to go to a higher level. The surgeon should form an opinion on the advisability of a knee disarticulation only after examining the zone of injury and the quality of tissues around the knee. The surgeon must then look into his or her crystal ball to see whether the leg will likely heal without pain. The quality of the soft tissue is the most important factor.

Decision-making in knee disarticulations really highlights the value of surgical experience and insight. Surgeons learn the technical ways to perform a procedure – where to cut, which muscles to use, and the anatomy of the nerves and vessels – and they also learn the range of indications for when a procedure may be appropriate. Only with experience, however, comes the knowledge of when it's truly best to do it and when it's best not to. Situations like those when scarring or insufficient padding would leave the area tender and uncomfortable are difficult to foresee but important to anticipate. While that knowledge is helpful, as much as we try, we cannot see into the future to know exactly how things will turn out. Sometimes, surgical outcomes are not perfect and some fine-tuning may be needed. We may realize after the initial amputation that a higher-level amputation is needed to try and lessen pain or to improve function. Initially, however, we must use our best judgment and make a decision without knowing what the ultimate outcome will be. We only really find out after the knee disarticulation heals whether the soft tissue can tolerate the end weightbearing pressure that leads to success. That's why, unfortunately, I need to say, “It's better when it's better and it's not when it's not.”

The Preparatory Prosthesis

Fitting a prosthesis as soon alter surgery as possible helps to combat edema. A preparatory prosthesis is frequently used for several weeks or months until the stump has stabilized before the "permanent" or definitive prosthesis is provided.

The socket of the preparatory prosthesis may be made of either plaster-of-Paris or a plastic material, and is attached to an artificial foot by a lightweight tube or strut, often called a "pylon." When indicated, a suction socket is used. Most pylons are designed so that the alignment of the foot with respect to the socket can' be changed when it is needed.

Although a variety of shoes may be worn with artificial limbs, the patient should consult with the prosthetist before selecting shoes to be used with the *prosthesis, because heel height is a major factor in alignment of the artificial leg.*

A belt about the waist is usually used to help keep the preparatory prosthesis on the stump properly. At least one prosthetic sock is worn between the socket and stump to provide for ventilation and general comfort. Most prosthetic socks are woven of virgin lamb's wool, but socks of synthetic yarns are available also. Prosthetic socks are used to prevent skin abrasion and to provide ventilation. They are available in several thicknesses - most commonly 1-ply, 3-ply, 5-ply, and 6-ply. Additional socks can be used to compensate for stump shrinkage if the amount of shrinkage is not too great. The prosthetist and therapist can suggest the sock or socks to be used, but only the patient can determine the proper selection.

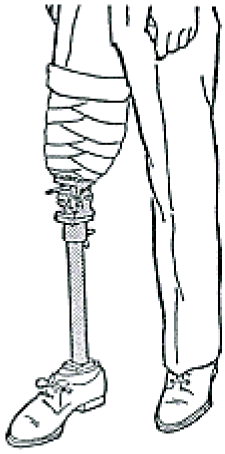
Prosthetic socks must be changed daily to reduce the chance of skin irritation or dermatitis.

Prosthetic socks require special care in laundering. Instructions are provided by each manufacturer.

A special woven nylon sock known as a prosthetic sheath is used by many amputees between the skin and regular prosthetic sock to provide additional protection from abrasion. The sheath also allows perspiration to escape to the prosthetic sock and thus to the atmosphere.

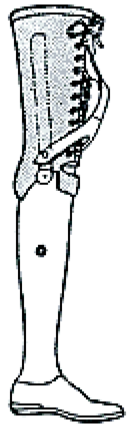
Special Note:

Regardless of the functions provided by the most sophisticated mechanical devices, the most important factors in the usefulness of an artificial leg are fitting of the socket and alignment of the various parts with respect to the body and to each other. Fitting and alignments are difficult procedures that require a great deal of skill on the part of the prosthetist and a great deal of cooperation on the part of the patient. During fitting and alignment of the first prothesis, it is necessary for the prosthetist to train the amputee in the basic principles of walking. Fitting affects alignment, alignment affects fitting, and both affect comfort and function. Extensive training is carried out later by the physical therapist.

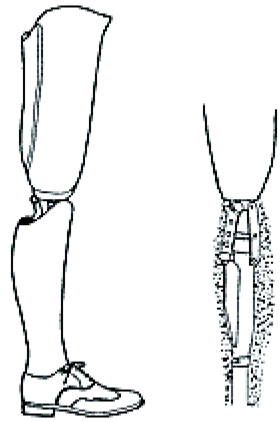


8-7 Knee-Disarticulation Prostheses

The knee-disarticulation prosthesis is very similar to the above-knee prosthesis, except for the lower part of the socket and the knee mechanism. Before the introduction of the present day polycentric knee units, sockets for the prosthesis were usually made of leather and metal hinges were used to attach the socket to the shin. This type of prosthesis is still preferred by a few preferred even though it is bulky and control of the leg during the swing phase is difficult. However, most prefer one of the polycentric designs where the knee mechanism can be installed within the shin due to its special design. The major objection to the polycentric units is that the knee protrudes slightly beyond the front of the shank when the amputee is sitting or kneeling. Leather sockets are held on by a lacing. Plastic sockets usually have a foam liner in the lower part for the bulbous end of the stump to slip by so as to keep the socket in place. All of the instructions given about use of the above-knee apply equally to the Knee-Disarticulation prosthesis.



Prosthesis for knee-disarticulation amputees that uses hinges on the outside if the socket.

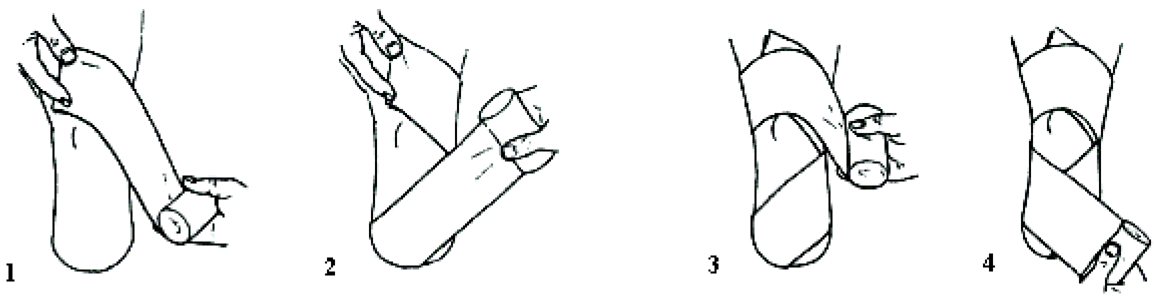


Prosthesis for knee-disarticulation amputee that uses a four-bar polycentric knee unit.

8-8 Bandaging Technique

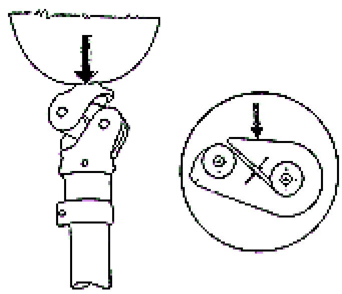
1. Start with the bandage held in place on the inside of the thigh just above the knee and unroll the bandage so that it is laid diagonally down the outer side of the stump while maintaining about two-thirds of the maximum stretch in the bandage.
2. Bring the bandage over the inner end of the stump and diagonally up the outer side of the stump.
3. Bring the bandage under the back of the knee, continue over the upper part of the kneecap and down under the back of the knee.

4. Bring the bandage diagonally down the back of the stump and around over the end of the stump. Continue up the back of the stump to the starting point on the inside of the thigh and repeat the sequence in a manner so that the entire stump is covered by the time the roll is used up. The end of the

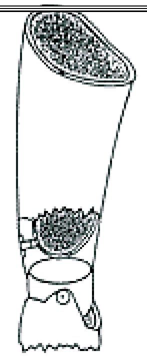


bandage is held in place with the special clips that are provided. It is important that the tightest part of the bandage be at the end of the stump.

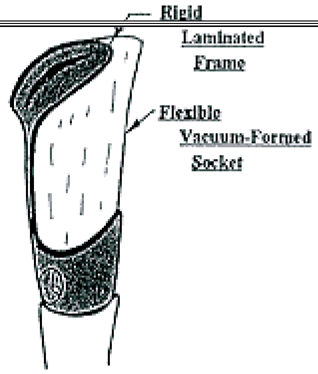
Fabrication of a Below-Knee ProsthesisWhether the prosthesis is to be crustacean or endoskeletal (often called "modular") type, the prosthetist usually begins by wrapping the stump with plaster-of-Paris bandages to obtain a negative mold. A positive model is made by filling the negative mold with a mixture of plaster-of-Paris and water, and allowing it to harden. After modification of the model to provide the proper characteristics to the finished socket, a plastic socket is formed over it. The first one is usually a test, or check, socket made of a transparent plastic to determine if further modifications are needed. A new method being used by many prosthetists for obtaining a modified model of the stump involves use of a computer and automatic machinery. Known a CAD/CAM (Computer-Aided-Design/Computer-Aided-Manufacturing), this method permits prosthetists to modify the model more easily since it does not require making and carving an actual plaster model. The socket is mounted on an adjustable leg for walking trials, and when both the prosthetist and the amputee are satisfied, the limb is ready for the finishing procedures. The exoskeletal shank may be of plastic-covered wood or all plastic. The endoskeletal type uses carved foam rubber over the supporting pylon and the entire prosthesis is encased in a either a latex or fabric stocking. Steps in the fabrication of a plastic prosthesis for a below-knee (trans-tibial) amputee:



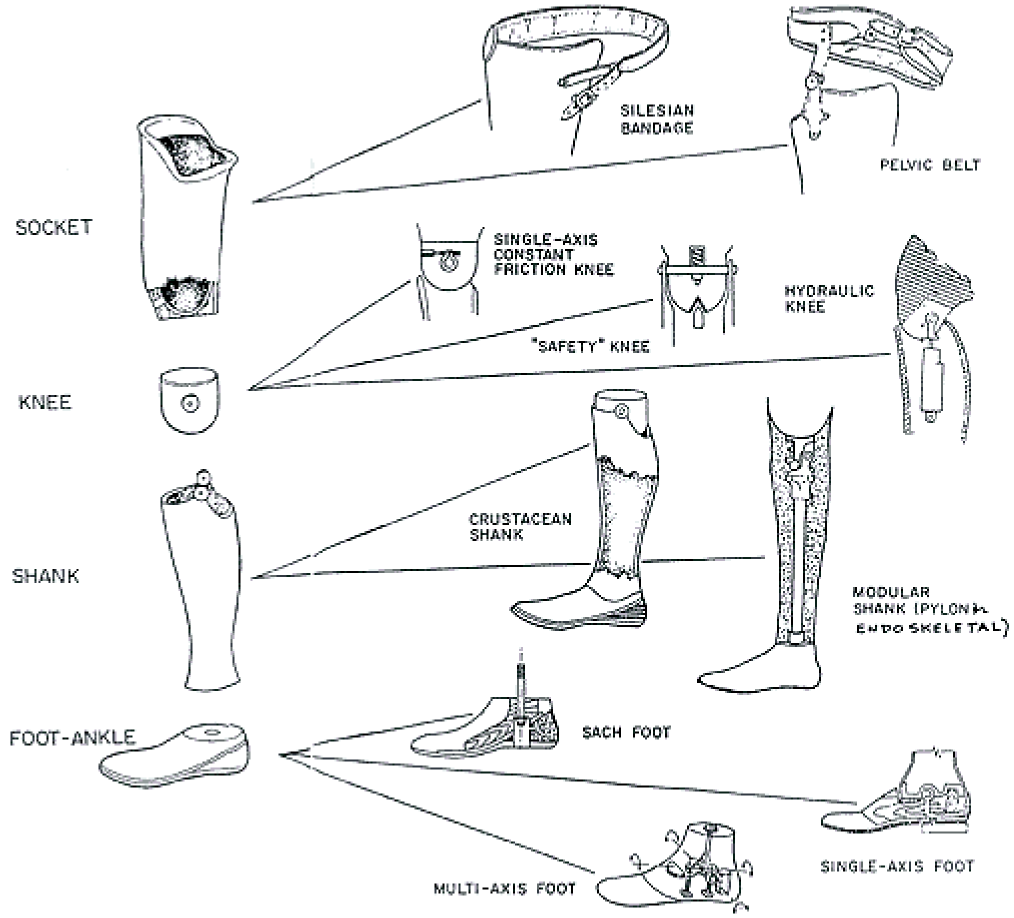
Schematic Drawing of a
Weight-Actuated Knee Brace



Rigid suction socket.



Suction socket with flexible walls.



Above Knee Prosthesis

Above knee prosthetic components

1. **Suspension :-** it is either self suspending (Suction using Valve in the socket) or External Suspension (Silesian belt , Pelvic Band and Shoulder Strap)
2. **Socket :-** it is only hard no soft socket because suction..
3. **Knee Joint Assembly :-** Articulation Polycentric knee mechanisms , Single axis and multi axis) **.**
4. **Knee Control:-**
   a. **Stance Phase Control**
      - Free Knee
      - Manual Knee
      - Semi automatic
      - Stance Flexion

   b. **Swing Phase**
      - Damper-Hydrolic
      - Extension Assis
      - Internal
      - External

5. **Shank**
   - Exoskeletal
   - Endoskeletal

6. Foot

- SACH
- Singl Axis
- Multi Axis
- Energy Foot
- ICRC Foot

7. Cosmoses :- Hard , Soft.

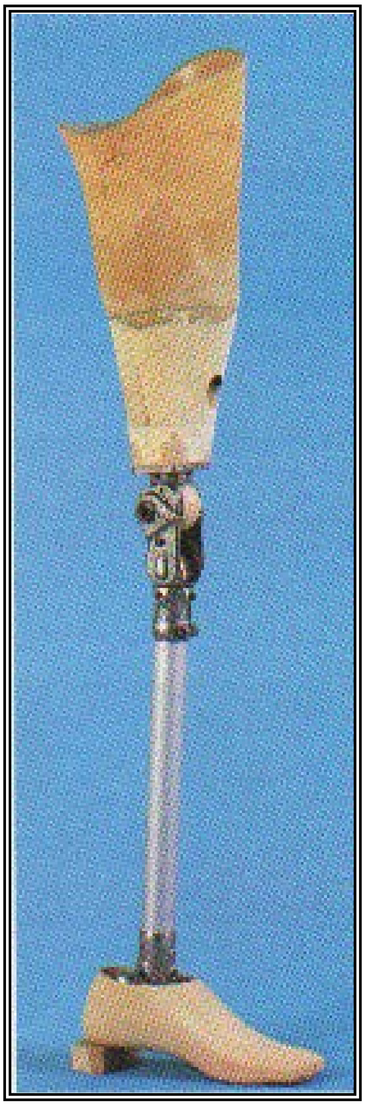


Fig 1

1. **Suspension** it must hold the limb securely and comfortable onto the patient. and it must allow the patient to move. The suspension used to assist the patient if he has poor control of the leg or not.

Type of suspension :-

a. **Suction :-** the patient wears the socket without any straps to hold on and the socket is very closer fit. The soft tissue is pulled down the into the socket as the patient pulls the sock through the valve hole. When he is completely into the socket a plug is put in the distal hole the air can not get back into the socket so a partial vacuum is created in side. This will stop the socket from falling. The patient must tense his stump muscles as the leg is lifted off the ground to help to hold the leg on.

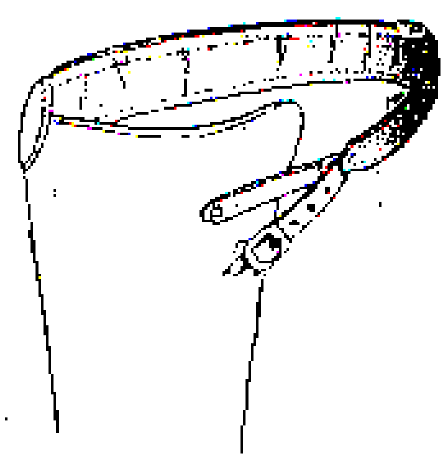
Advantages :-

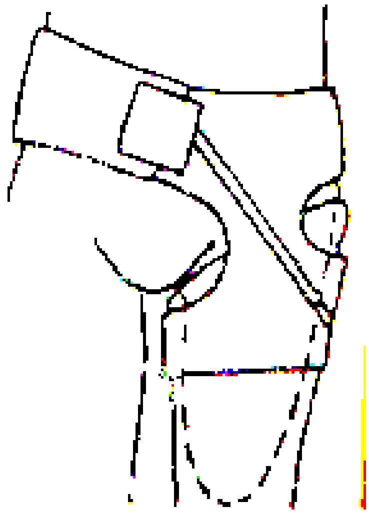
- No straps to rub or restrict movement.

Disadvantages:-

- Careful fitting needed to make sure of good fit otherwise air will inter and leave the socket with each step and will causes noise.
- Sweating is increased because no sock is present to absorb it.
- Putting on and taking off is difficult specially for those with poor hand

b. **Silesian Belt :-** this is a soft belt wrapped around the patient at waist level.





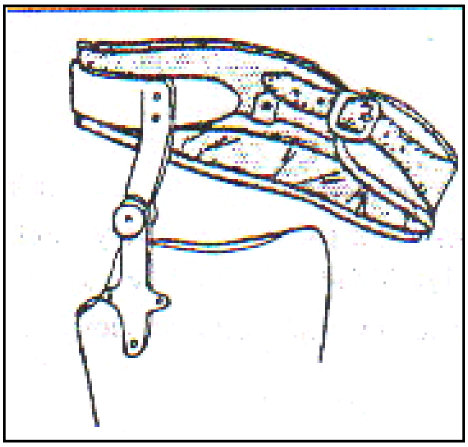


Fig 2

Advantages :-

- Secure suspension but not restrictive to movement.
- Simple to fit and repair.
- Made from locally available materials.

Disadvantages:-

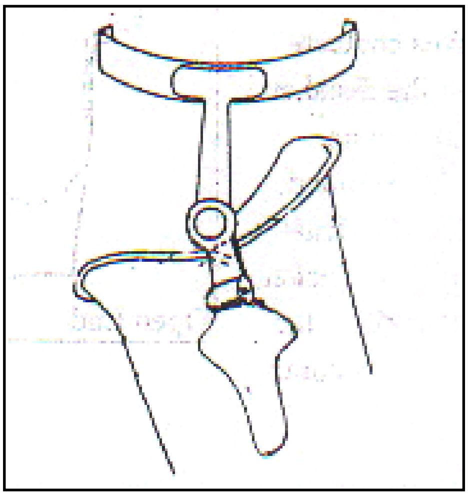
- Can causes the socket to internally rotate if not correctly set up.

c. Rigid Pelvic Band RPB :- it consist of a strong steel strip which encloses about 1 / 3 of pelvic on the side of amputation. It design is useful when trying to control trunk lateral bending. There are several different types of rigid pelvic band hinge set up:-

A. Latheral Bending :- The steel hinge has external hinge in it which allows the leg to be removed into abduction. This often used when the

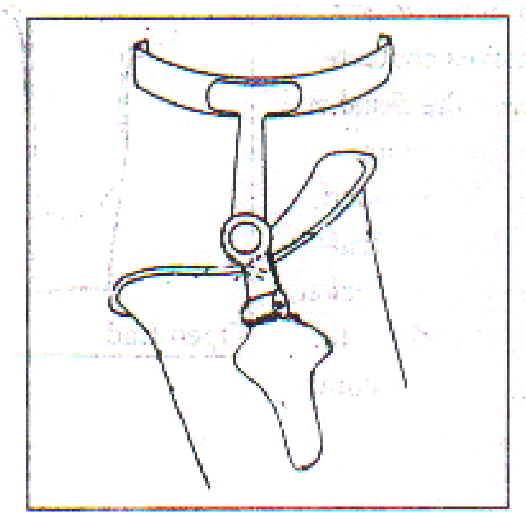
patient has good control in **Flexion / Extension** , **Abduction / Adduction. But need help in controlling rotation.**

Fig3



B. **Double Swivel :-** this type allows freedom in all direction including rotation .

Fig 4



These type rigid suspension are not very common throughout the world and are most used with very old patients with very short stumps.

C. **Shoulder strap:-** This pass over the opposite shoulder it is able to be attached and remove.

Advantage of the Suspension:-

1. To hold the limb securely and Comfortable .
2. Allow the patient to move the leg away .
3. Assist the patient if he has poor control

Causes of noise during Walking with the prosthesis of suction socket:-

1. The air leaking between the stump and socket
2. Looses in the knee or ankle joint.
3. Piston action

The causes of piston action are :-

A. The socket too big

B. Improper suspension.

Adductor roll causes:-

a) Too small socket special anterior medial coroner .

b) No space in adductor channel to contain all tissue inside channel.

c) Upper trim no more than lower below ishial seat.

2. **Socket :-** The most important components is the socket. If the socket is correctly fitted the prosthesis will function well.

There are two types of the socket:-

a. **Total contact :-** where the end socket make contact with the distal end of the stump. It will give a better result for the patient but will be more difficult to manufacture
b. **Open ended :-** The distal end of the socket is open from the end stump it is easy to manufacture especially if using aluminum or wood..

The most common used material either composite material such as lamination like Trans – Tibia socket (Chemical Plastic) or polypropylene material.

3. Polycentric knee mechanisms

Alignment stability can be enhanced through the use of polycentric knee mechanisms. A polycentric knee mechanism is any device where the instantaneous centre of rotation of the knee changes its position as the knee flexion angle increases or decreases. Kinematically all polycentric devices, where stability is controlled by the location of the instantaneous centre of rotation (the instant centre), are of the same class. However, there is an infinite variety of kinematic arrangements possible, each with its own special functional characteristics. The following discussion is an attempt to explain the behaviour of such devices assuming, in the beginning, that there is no brake-type friction acting simultaneously as part of the function of a particular device. There are several ways that polycentric motion between the thigh piece and shank can be created knee mechanism.

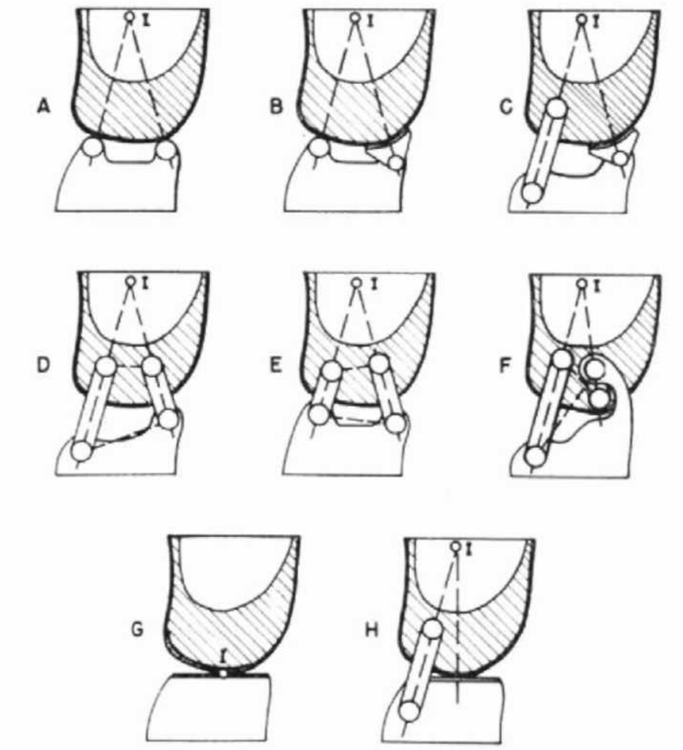


Fig 5 polycentric devices

Figure 5 displays schematically most of the polycentric prosthetic knee mechanisms that have been used to date. In each diagram the point I represents the instantaneous centre of rotation of the thigh piece or knee block with respect to the fixed shank with the knee in full extension. In many cases, it has been possible to locate the point I in exactly the same position when the knee is fully extended.

Case A :- represents the double-skid mechanism often used for so-called "physiological" knee mechanisms. In this case the shape of the upper condylar surface determines the manner in which the instant centre changes its location with knee

flexion. Point 1 is located at the intersection of the two lines which are perpendicular to the surfaces in contact at the two skid points.

Case B:- is a simple variation where one skid point has been replaced by a pivoted slider. Point I is again located by two lines, one of which passes through the slider pivot perpendicular to the upper condylar surface.

Fig. 5. Polycentric knee

In case C:- the rear skid point has been replaced by a two-joint link and the centre line of the posterior link becomes one of the lines required to locate point I.

Cases D and E:- are four-bar linkages with the same instant centre I but obviously different flexion characteristics. The knee block and shank structure form the second pair of "bars" as shown by dotted lines.

Case F:- is also a four-bar linkage. The upper pivot of the anterior two-joint link is attached to the shank in this case.

Case G:- represents a design involving pure rolling rather than a skidding action. In devices of this type, the instant centre I is always at the point of rolling contact.

Case H:- is also somewhat different. The posterior two-joint link acts in the same manner as in the four-bar linkage. The anterior guidance is provided by the skidding of the surface of knee block along a flat surface attached to the shank. Since the shank surface is flat and horizontal, the line which locates I is always perpendicular to the shank surface at the point of contact.

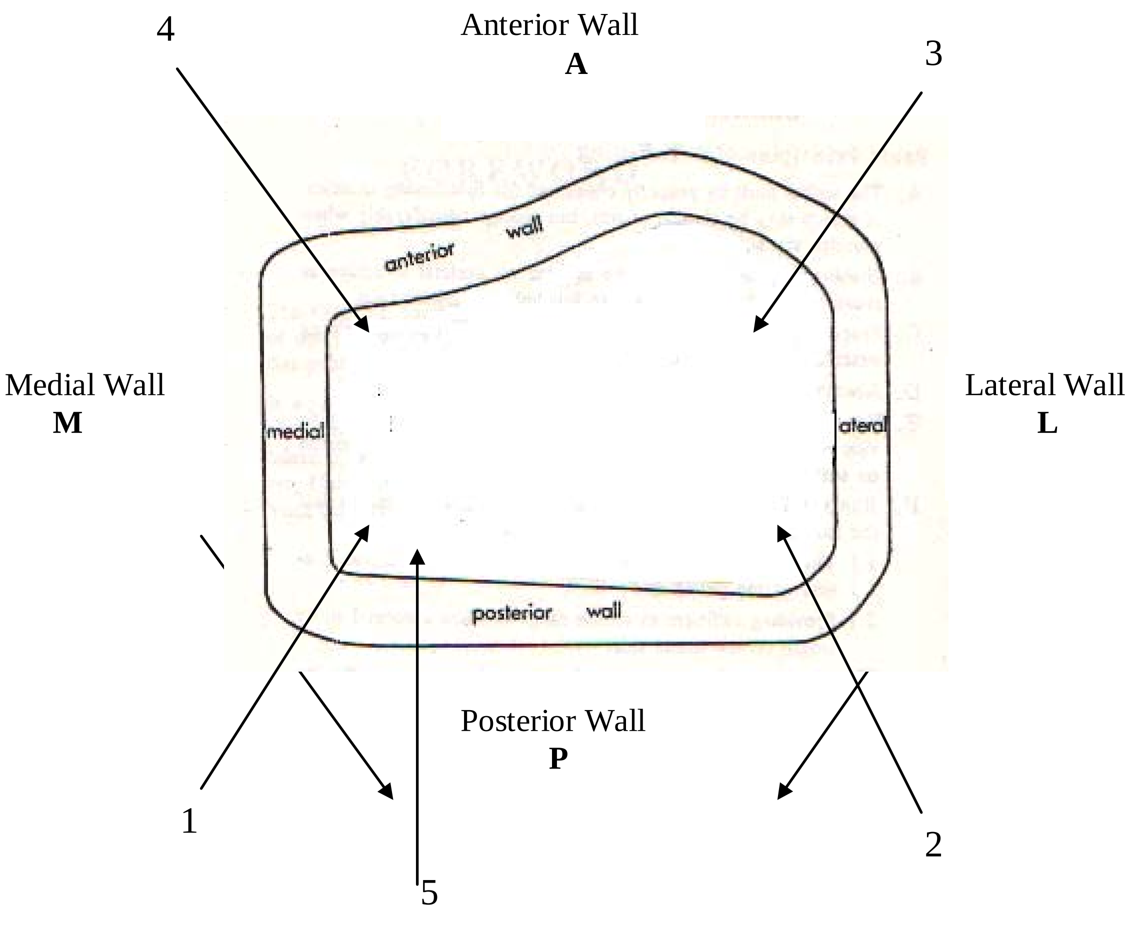
The quadrilateral socket shape

The socket shapes shown in Figure 6 are based upon the requirements as discussed in the previous section. The shape is not a duplicate of the free stump since soft tissue must unavoidably be compressed in areas where higher pressures must be tolerated on soft tissue, particularly in the Scarpa's triangle area along the anterior aspect of the stump and in thegluteal region of the posterior brim. Regions of firm musculature such as along the rectus femoris muscle are channelled to avoid excessive pressure as required. Tendon insertions on the pelvis such as the hamstring tendons or adductor longus must be accommodated in appropriate channels in the posterior-medial and anterior-medial corners of the socket. The width of the medial wall of the socket is defined by the anatomical dimension measured between ischium and adductor longus. If this dimension is incorporated into the socket accurately, the pubic ramus will always be supported well above the medial brim of the socket. If the medial dimension is too wide, the ischium will slide forward during weight bearing with inevitable painful pressure against the pubis.

The contours of the socket must always be considered in three dimensions. One of the most difficult problems in the fitting process is to achieve the proper degree of tightness of fit along the length of the stump. With open-end sockets carved from wood the socket circumference dimensions were often less than the free stump circumference with the result that the soft tissues of the stump were pulled deeply into the socket as the socket was donned. With the modern total-contact suction socket, this reduction in socket circumference is often less and the socket dimensions more nearly approximate the free stump measurements. The pressure pattern created between the socket and the tissues of the stump and pelvis is a function of the forces and moments being transmitted at any instant during the walking cycle. The pressure pattern varies dramatically over the walking cycle and it is remarkable that a socket of fixed shape can transmit these pressures comfortably for long periods of use.

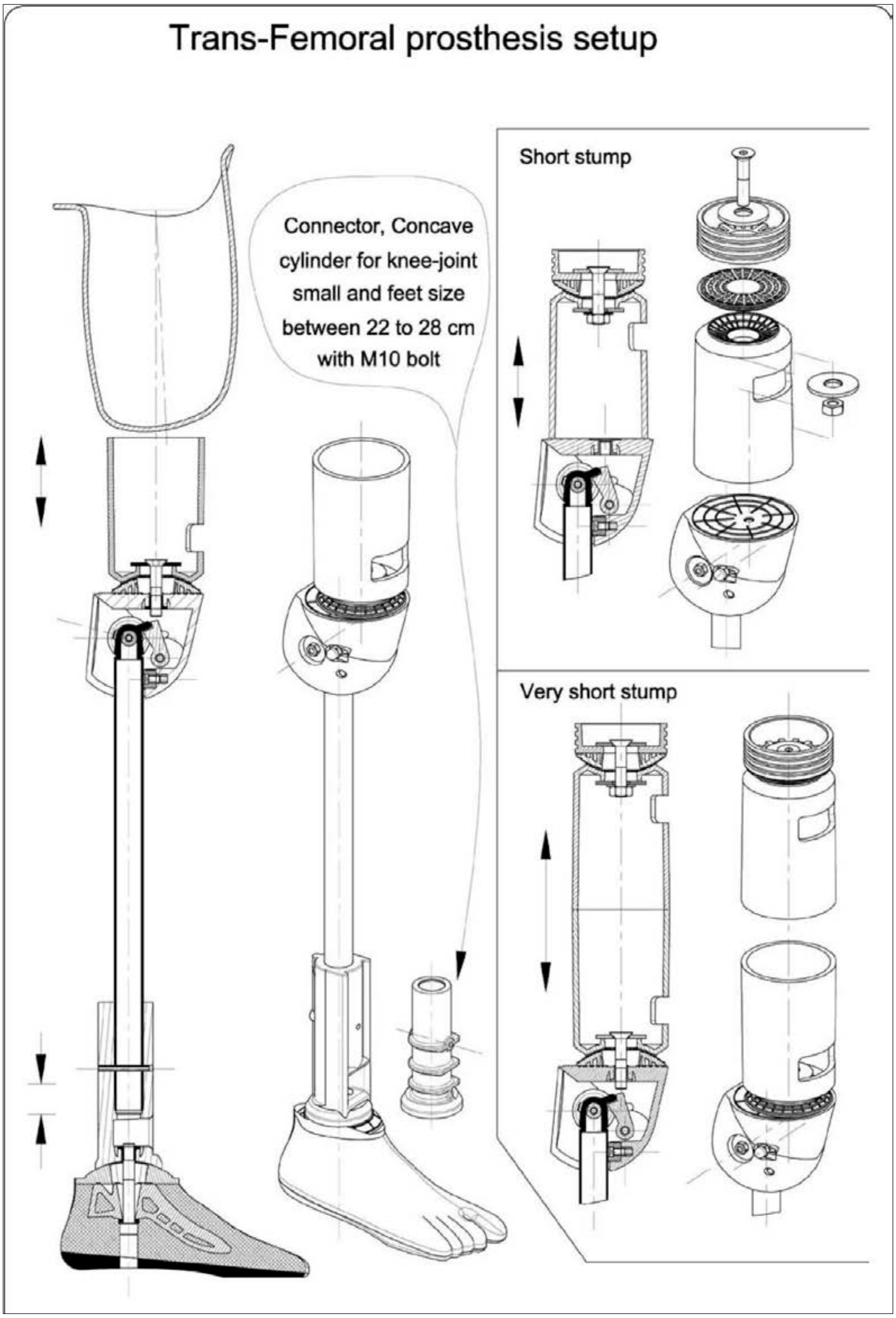
Relife Area from the Wall of Quadrilateral socket:-

1. **Hamstring Area .**
2. **Gleuteal Area.**
3. **Rectos Femitos Area.**
4. **Abductor Area.**
5. **Scarp Triangle Pulge Area.**



Function of Quadrilateral socket Wall:-

1. **Anterior :- Press the stump back ward to located weight bearing. W / B.**
2. **Posterior :- Weight Bearing. W / B. Area.**
3. **Medial :-**
    a. **Medial – Lateral Stability.**
    b. **There is a channel to contents the Adductor muscles Tendon.**
4. **Lateral:- Lateral - Medial Stability.**



Bench alignment systems

The basic means employed in many above-knee prostheses to achieve knee stability is to align the knee axis in a location such that the load carried by the weight-bearing prostheses always passes ahead of the knee axis and forces the prosthetic knee against a mechanical stop in the fully extended position. This simple principle is employed in all above-knee prostheses regardless of other means used to achieve stability and will be referred to as alignment stability in the following discussion.

Alignment stability is often ensured by a process which has become known as bench alignment. Two somewhat different philosophies for bench alignment have been proposed. In Germany the prosthesis is often assembled in a fixture using a plumb line viewed from the lateral side which passes downward from the centre of the socket brim through a point on the bisector of the length of the foot as shown in Figure 1. The trochanter is sometimes used as the upper reference point. To achieve what may be described as a rolling action of the hip over the foot the heel of the foot is elevated slightly in the reference position. The bench alignment diagram displays the prosthesis in a position corresponding to the point where the amputee would begin to roll over the ball of the foot in walking, i.e., in a position where the hip joint is close to the highest point in its trajectory. The clearance under the heel is often called a "safety factor". An increased clearance results in a more rapid transfer of weight to the ball of the foot and improves knee stability at heel contact.

The position of the knee axis relative to the vertical reference line is dictated by the combination of knee kinematics and friction brake action inherent in a particular mechanism and very definite rules have been established for different combinations of knee and foot designs.

In the United States a similar plumb line reference system has been used which has the trochanter as the upper reference point and which locates the ankle joint directly under the trochanter as shown in Figure 2. Rules have been established for locating the knee joint on or behind this reference line which has been called the TKA line. In the American system the heel is shown in contact with the floor in the reference position. This system has evolved because of the need to have a convenient way to check bench alignment prior to walking trials with adjustable devices without the need for special holding or limb assembly fixtures as are common to some European systems.

The American system may result in a prosthesis which is somewhat longer than a similar prosthesis if the pelvis level is checked with the limb in the alignment reference position. As the American prosthesis rotates forward over the ball of the foot toward the German reference position, it is clear that the heel would rise from the floor and the hip joint would be elevated slightly. This explains in part the controversy which often occurs between the American prosthetist who prefers to construct the prosthesis shortened a few millimetres to make it easier for the amputee to walk and the physician who insists on a level pelvis with the prosthesis in the alignment reference position.

Errors in both systems can result when the trochanter is used as the upper reference point. It requires that the alignment be checked with the amputee wearing the prosthesis and precise location of the point of contact of the head of the trochanter against the lateral brim of the socket is often difficult.

The reference line shown in Figure 3 is suggested as an alternative which is particularly well suited to the fitting of the quadrilateral socket shape. The upper reference point is established at the bisector of the interior medial wall of the socket. In the modified American system the new reference line becomes the MKA line and the knee joint is located on the medial aspect of the prosthesis rather than the lateral side as with the use of the TKA line.

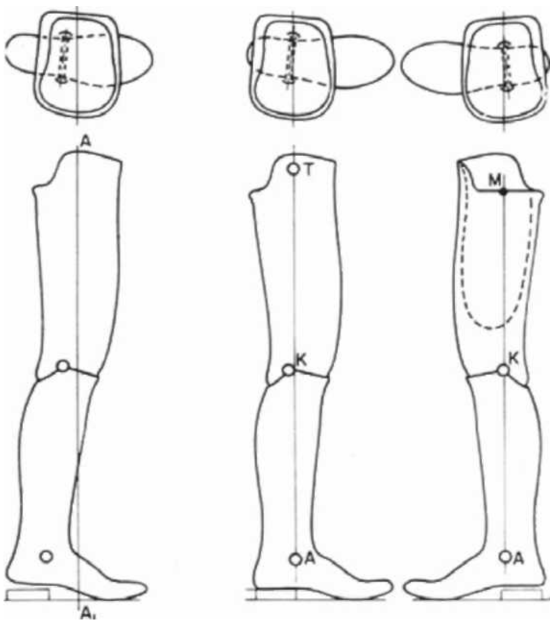
When using the TKA line, the knee axis is located on the lateral side of the prosthesis and for a typical prosthesis the knee axis is located approximately 6 mm (1/4") posterior to the TKA line.

The knee axis is typically aligned in 5 degrees external rotation, as necessary to prevent lateral movement (whip) of the foot in the swing phase. The medial end of the knee axis is forward of the lateral end by approximately 6 mm. Therefore, when using the MKA reference line along the medial aspect of the prosthesis, the knee axis can be located directly on the MKA line for a typical active above-knee amputee with medium to long

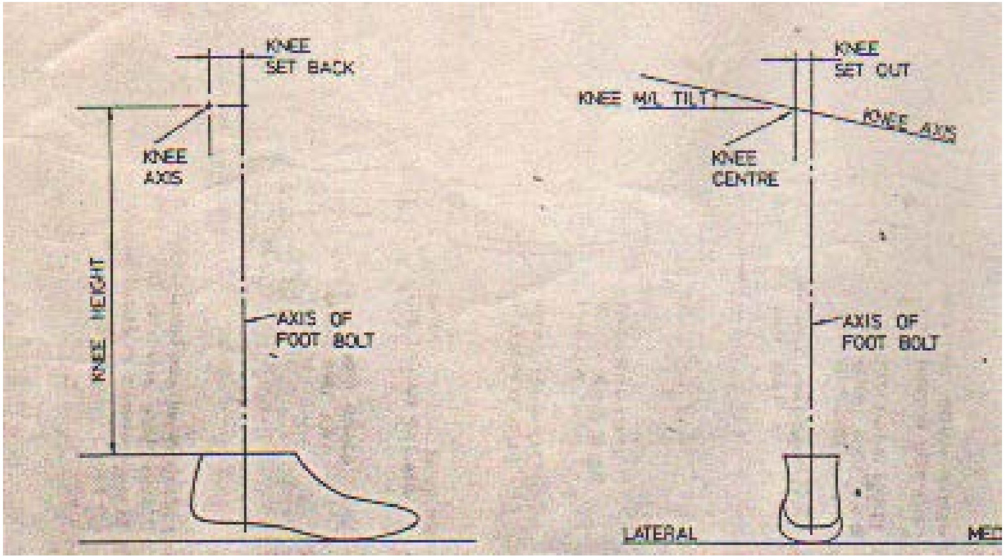
stump.

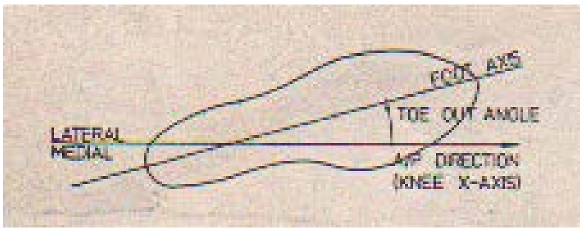
The usefulness of the German air space under the heel is also acknowledged and where greater knee security is desired, the use of increased heel rise in the prosthetic foot is encouraged.

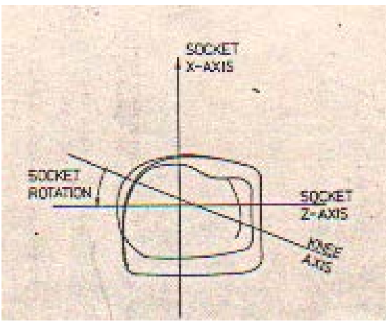
A spacer under the heel 6 to 10 mm thick at the time of bench alignment will give the amputee greatly increased knee security at heel contact. The prosthesis will not have its length increased with this procedure since the distance to the ball of the foot remains the same.

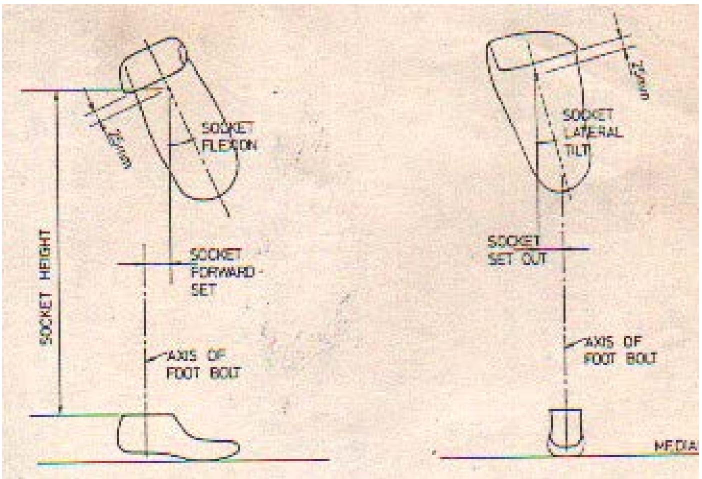


Figs. 1,2 and 3. Bench alignment systems. Fig. 1 (left) German, fig2. (centre) TKA reference, fig. 3 (right) MKA reference.


KNEE
SET BACK
KNEE
AXIS
KNEE HEIGHT
AXIS OF
FOOT BOLT
KNEE
SET OUT
KNEE M/L TILT
KNEE AXIS
KNEE
CENTRE
AXIS OF
FOOT BOLT
LATERAL


FOOT AXIS
TOE OUT ANGLE
LATERAL
MEDIAL
A/P DIRECTION
(KNEE X-AXIS)


SOCKET
X-AXIS
SOCKET
ROTATION
SOCKET
Z-AXIS
KNEE
AXIS


SOCKET
FLEXION
SOCKET HEIGHT
SOCKET
FORWARD-
SET
AXIS OF
FOOT BOLT
SOCKET
LATERAL
TILT
SOCKET
SET OUT
AXIS OF
FOOT BOLT
MEDIAL

Voluntary control of knee stability

The brake knee mechanisms shown in Figure 5 provide what might be called automatic control of knee stability. When operating properly, the brake friction is created automatically each time the prosthesis assumes its weight bearing function.

The brake action is generally beneficial in level walking, particularly on rough surfaces. In some cases there may be difficulty in flexing the knee at the end of stance phase when walking on slopes and stairs.

Trans Femoral Fitting Problems

A. – Adductor longus Discomfort :- Medial and Lateral Wall

1) Too high the medial wall of Quadrilateral socket.

2) Anterior Pelvic tilt.

3) Insufficient the radius to the medial wall.

4) Insufficient the counter force of the anterior wall .

5) A – P diameter dimension on the socket too greet .

6) In abdicate the adductor longus in this channel.

B.– Hamstring area discomfort :-

1) Too thick the posterior wall at ischeal seat

2) .Too tight (small) socket.

3) No proper placement .

4) Counter of gluteal muscles 20 mm.

C. Ischeal seat discomfort :-

1) Seat contact too far anterior.

2) Seat contact too far posterior.

3) Seat too wide.

4) Pain.

5) No proper place.

D. Trochonter area discomfort:-

1) Excessive pressure from poor socket shape.

2) Lateral wall is too low edge will dig into it.

3) The gap is causes by (M – L)too large.

E.Distal end discomfort:-

1) Volume changes.

2) Skin problems.

3) The length of the socket not correct.

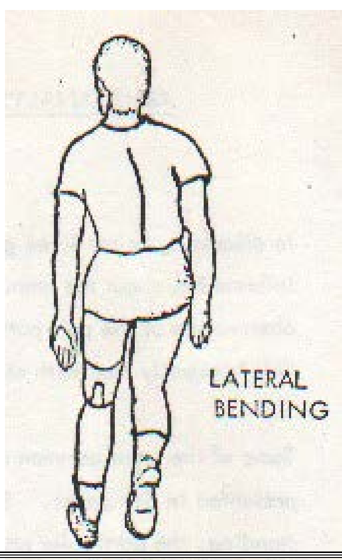
<u>Above – Knee Gait Analysis.</u>

The common above – knee gait deviations will be consider are:-

1. Lateral Bending of the Trunk.
2. Abducted Gait.
3. Circumduction .
4. Vaulting.
5. Rotation of foot on Heel strike.
6. Uneven Arm swing .
7. Uneven Heel rise .
8. Terminal Swing Impact..
9. Swing phase Whips
10. Foot Slap..
11. Lumber lordosis.

1) Lateral Bending of the Trunk

Description :- Trunk bends toward the amputated side when the prosthesis is in stance phase. This movement shifts the amputee's center of gravity toward his prosthesis.



When to Observe : from just after heel strike to mid stance.

How to Observe:- from behind the patient.

Causes :-

a. Short Prosthesis.

b. **Insufficient support by lateral wall of socket.**

c. **Abducted socket.**

d. **Pain and discomfort on lateral distal of the stump.**

e. **Week abductors.**

2) Abducted Gait :-

Description :- the width of the walking base is significantly greater than the normal range of 50 mm – 100mm .

When to Observe : During the period of double support.

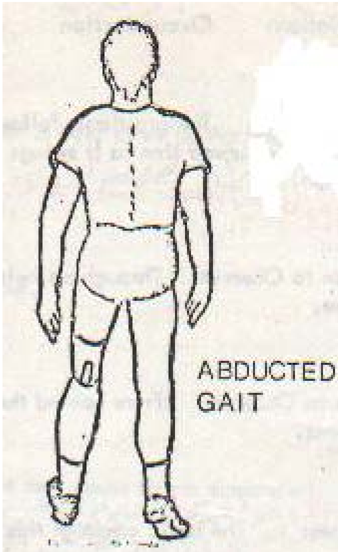
How to Observe:- from behined.

Causes :-

I. **Prosthesis too long.**

II. **Pain or discomfort of the crotch area.**

III. **Contract abductors of the stump.**



3) Circumduction.

Description :- the prosthesis follows a laterally curved line as it swing.

When to Observe : Through swing phase.

How to Observe:- from behind the patient.

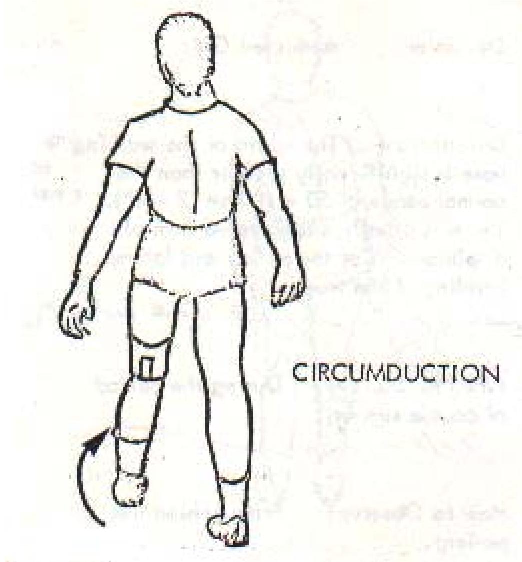
Causes :-

i. Too long.

ii. Piston action between the stump and socket.

iii. Too small socket.

iv. Foot set in planter flexion.



4) Uneven Heel rise

Description :- The prosthetic heel shows a smaller rise than the sound heel.

When to Observe : During first part of swing phase.

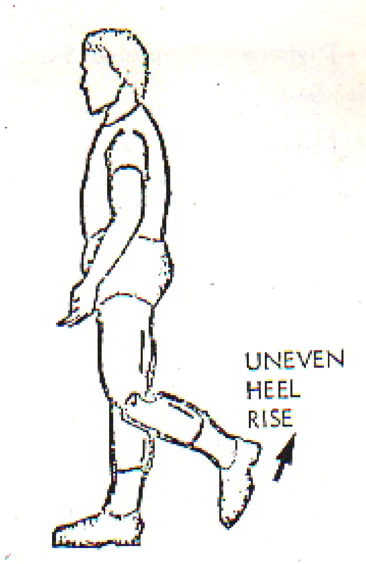
How to Observe:- from the side.

Causes :-

a. Insufficient friction on prosthetic knee.

b. Excessive friction on the prosthetic knee.

c. Absence of extension.



5) Terminal Swing Impact

Description :- The knee goes into extension.

When to Observe : At the end of swing phase.

How to Observe:- from the side.

Causes :-

a. Too much tension on the extension.

b. Full extension digs the heel into the ground.

6) Swing phase Whips

Description : **A-** Medial whip – at toe –off the heel moves medially.

B- Lateral whip – the movement medial at toe –of the heel moves laterally.

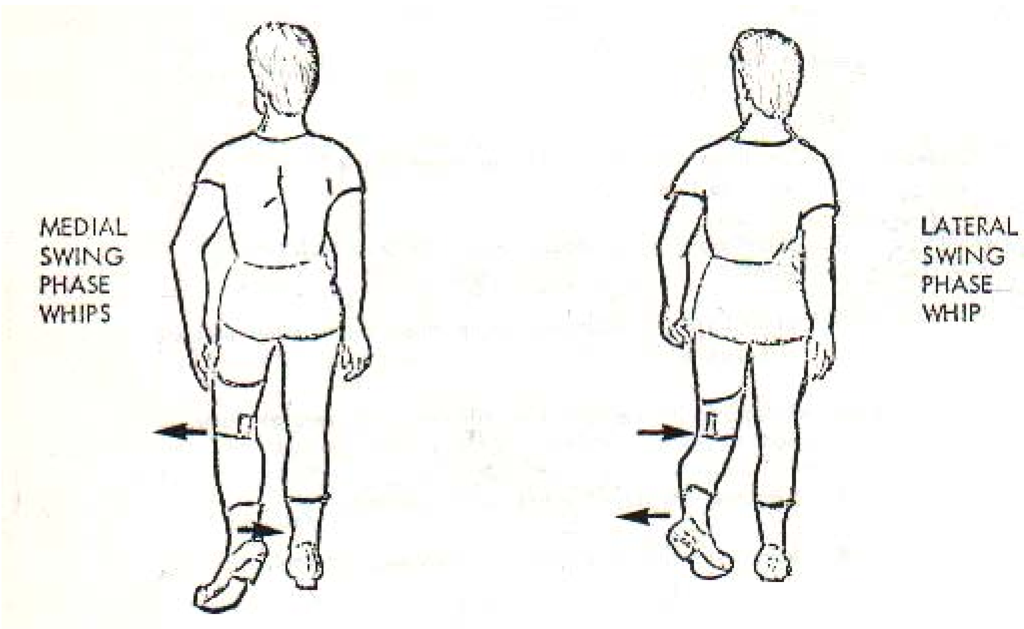
When to Observe : just after toe –off.

How to Observe:- from behind the amputee.

Causes :-

A. Socket too tight.

B. Week stump.



7) Foot Slap

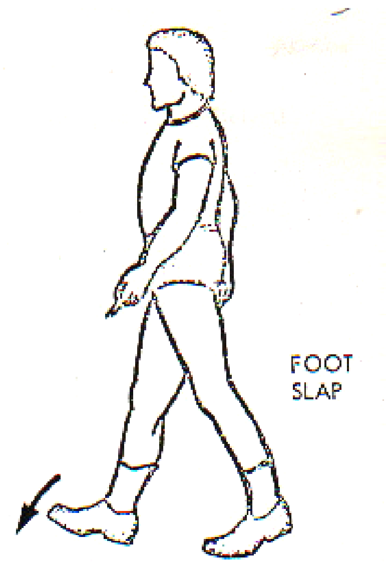
Description :- the foot planter flexes too rapidly and strikes the floor with a slap.

When to Observe : just after heel strike.

How to Observe:- from the side.

Causes :-

The foot not offer enough resistance to motion of the foot as weight is transferred to the prosthesis.



8) Lumber lordosis.

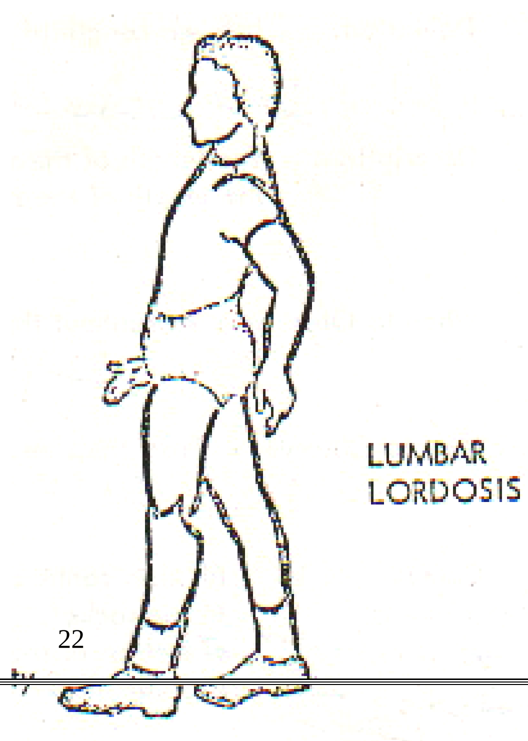
Description : The normal convexity of the lumber area is exaggerated when the prosthesis in stance phase .

When to Observe:- through stance phase.

How to Observe:- from the side.

Causes :-

1. Flexion contracture of the hip.
2. Insufficient initial flexion of the socket.
3. Insufficient support from brim of anterior socket wall.
4. Weak extensors of the hip.
5. Painful ischial bearing

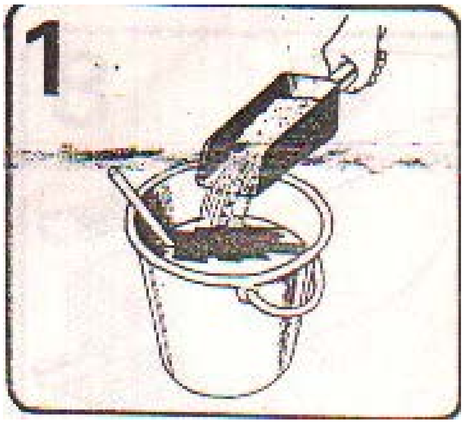


2-1 Preparing the Plaster Model of the Stump. (Modification of Positive)

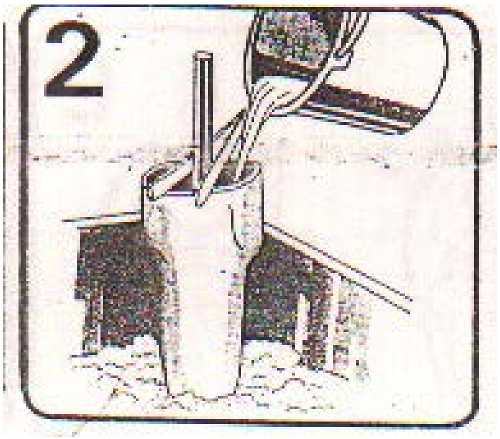
The plaster – bandage wrap cast of the stump is used as a mould in making the plaster model of the stump the object of the modification is to increase socket – contact pressure where the forces between stump and socket must developed and decrease contact pressure in sensitive area if we need greeter pressure from any area we must removed more plaster from the corresponding areas on the model this model should be examined and the prominences and sensitive areas which will support weight, such as the medial tibial flare and the patellar tendon in the final socket.

To make the positive model we follow the following procedure :-

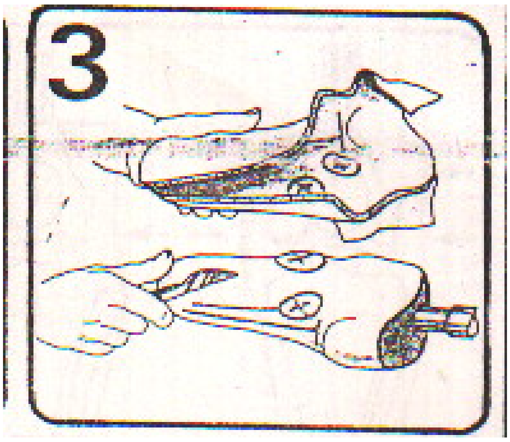
1. Prepare the liquid plaster by mix the Plaster of Paris with water.



2. Fill the mould with liquid of Plaster of Paris . you must insert iron pipe with vertical position , be careful the pipe not reach the end of the wrap cast. This will serve in the future for the bench –vise operation.



3. After the plaster has set for two hour , stripe off the wrap .the model is now ready for modification .

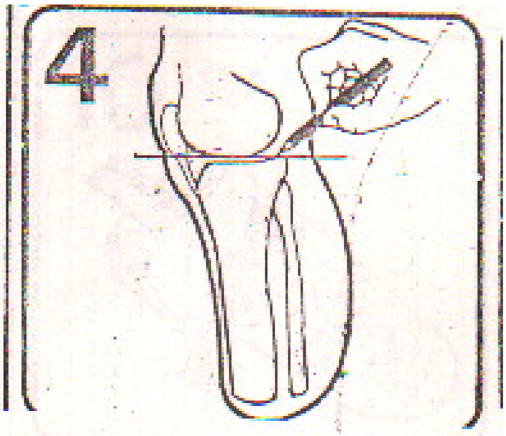


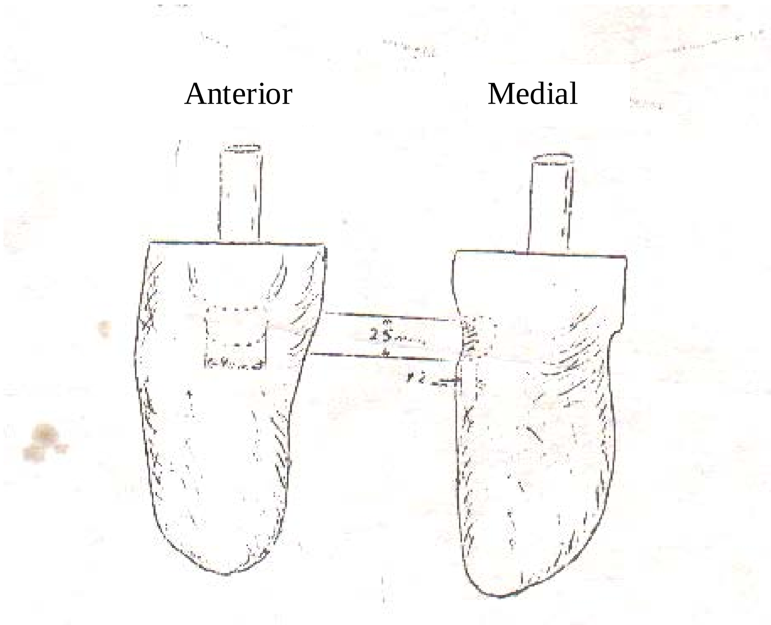
2-2 Modifying the Patellar Tendon Area:-

Check the length of the stump and check all marks and inspected for any mark distorted.

- Cut away the model midway between the lower edge of the patellar and tubercle of the tibia to a depth approximately 12 mm.

- The channel thus formed should have a height of approximately 25 mm.the modified area which is seen from the front have a width of approximately 40 mm.





2-3 Check Mediolateral Measurment :-

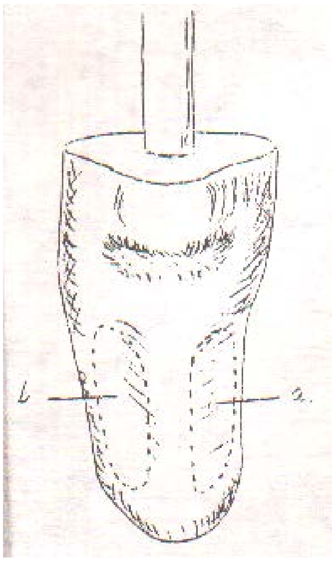
Using the measurement of the mediolateral stump diameter, check the model to see whether the cast has been distorted mediolaterally. If the model is too wide, shave away plaster from both sides until the measurement are correct.

2-4 Modification of the Anterior Surface :-

The anterior surface of the model should be modified downwards along side of the anterior tibial crest.

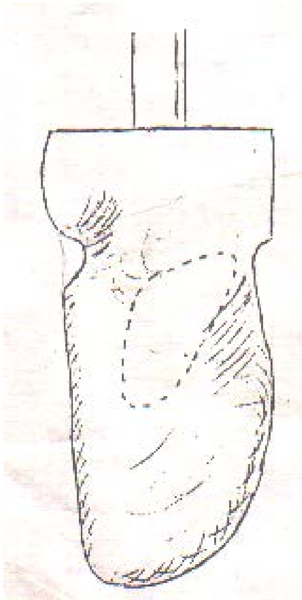
a - Shave off a minimum of 3mm. of plaster all along the anteromedial surface of the tibia, extending from below the medial flare to within 25mm. of the distal end of the tibia.

b - Shave off from 3 – 6 mm of plaster from the anterolateral surface of the stump model, extending from below the lateral condyles within about 25mm. of the distal end of the tibia.



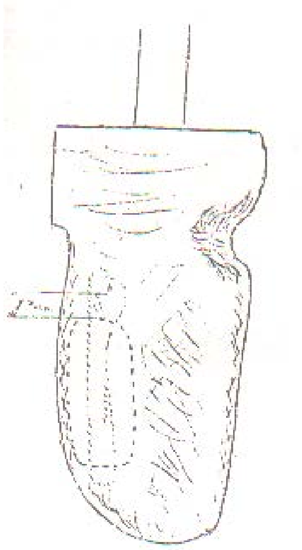
2-5 Modification of the Medial Tibia Flare :-

Modify the areas of the medial tibia flare by smoothing the cast and shaving off material according to the amount of soft tissue on the individual stump. Shave off at least 2- 3 mm of plaster at the deepest point, blending in with the previous modification of the anteromedial surface of the tibia.



2-6 **Modification of the Lateral Surface:-**

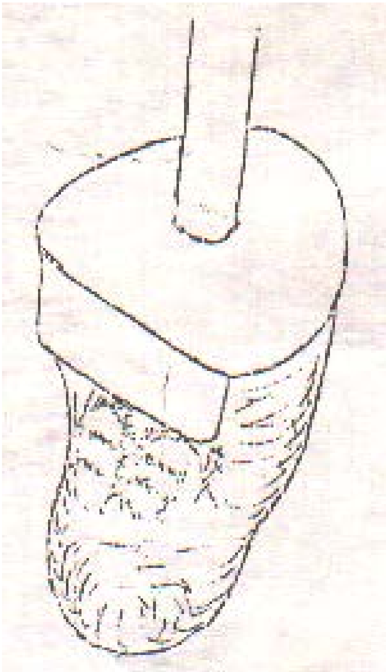
To ensure lateral stability, define contact pressure is provided for against the lateral surface of the stump. Depending on the characteristics of individual stumps the model should be modified along the lateral aspect removing plaster to flatten model and the emphasize contact pressure in this region. Minimum of about 3-5 should be removed the lateral surface of the model, starting 18mm blow the head of fibula blending with the previous modification of the anterior surface of the tibia.



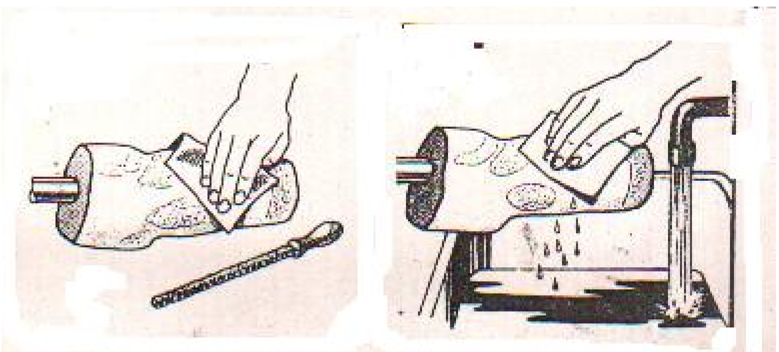
2-7 **Modification of the Popliteal Area:-**

By shaving away plaster to the depth fingerprints from condyles of the knee approximately 50mm.

Note :- never touch the hamstring tendon .



2-8Smoothing of the Positive Model :-



The model is ready for use to fabrication the soft socket and hard socket.