Partial foot Prosthetics

Course Work Manual

ICRC

(INTernational Committee of the Red Cross)
Aknowledgements

Substantial parts of the information and reference material provided in This Technical Manual for Lower Limb Prosthetics has been compiled from various medical and university sources. Without their long practice, know-how and extensive publications, this manual would simply not exist. We would like to mention in particular:

Course Work Manual, Carson Harte and Anne Henriksen, National School of Prosthetics and Orthotics from Phnom Penh, Cambodia:
- Partial foot prosthetics
- Ankle disarticulation prosthetics
- Below knee prosthetics
- Knee disarticulation prosthetics
- Above knee prosthetics
- Hip disarticulation prosthetics.

Clinical aspects of Lower extremity prosthetics, Trans-tibial, Symes and Partial foot amputations, The Canadian Association of Prosthetists and Orthotists.

Traité d’Anatomie Artistique, Dr. Paul Richer, Inter livres.

Lower Limb Prosthetics, 1990 revision, New York University Medical Centre.

Lower Limb Prosthetics, 1990 revision Prosthetics and Orthotics, New York University Post Graduate Medical School.
# PARTIAL FOOT PROSTHETICS

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SECTION - 1

ANATOMY OF THE FOOT
BONY ANATOMY OF THE FOOT

The human foot is composed of 28 individual bones divided into 3 groups - The Tarsals, the Metatarsals and the Phalanges.

Tarsals:

This is the most proximal (nearest to the body), and the strongest part of the foot. It is also called the posterior part of the foot. The Tarsal is composed of seven bones.

Those 7 bones are:
- Calcaneus.
- Talus.
- Cuboid
- Navicular
- 3 Cuneiforms  - 1st. Cuneiform (medial)
  - 2nd. Cuneiform (middle)
  - 3rd. Cuneiform (lateral)

For the prosthetist, the most important surface landmarks are the posterior prominent part of Calcaneus (anchor point for the Achillea tendon), and the Tubercle of Navicular.
Metatarsals:

Located between the Talus and the Phalanges (toes). It is composed of 5 bones. The 5 metatarsals are numbered, starting with Hallux (big toe) as the 1st. Thereafter follows the 2nd, 3rd, 4th and 5th. With the 5th Metatarsal being the laterally placed little toe.

Under the distal end of the 1st metatarsal, are located two small bones called Sesamoid bones.

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Phalanges:

There are 14 Phalanges. 3 for each of the 2nd, 3rd, 4th and 5th toes and 2 for the 1st toe. The Phalanges are named proximal, middle and distal (the furthest away from the body) phalanx.

The Phalanges will in most partial foot amputations be removed.
DORSAL VIEW

- Distal Phalanx
- Middle Phalanx
- Proximal Phalanx
- Distal Inter-Phalangeal joint
- Proximal Inter-Phalangeal joint
- Phalangeal-Metatarsal joints
- Metatarsal-Tarsals joints
- Cuboid
- Talus
- Head
- Body
- Base of 1st Metatarsal
- 1st Cuneiform
- 2nd Cuneiform
- 3rd Cuneiform
- Navicular
- Calcaneus
Partial foot prosthetics

LATERAL VIEW

Navicular
Cuneiform
Cuboid
Talus
Calcaneus

14 Phalanges  5 Metatarsals  7 Tarsals

MEDIAL VIEW

Navicular
Cuneiform
Calcaneus
Talus

14 Phalanges  5 Metatarsals  7 Tarsals
The arches of the foot.

The foot is a mobile weight-bearing structure. The bony architecture, reinforced and maintained by ligaments and influenced by muscles, forms arches: longitudinal and transverse.

These arches are important in absorbing shock loads and balancing the body. The medial longitudinal arch transmits the weight of the body to the ground in stance and transmits the weight to the great toe in gait.

**Medial longitudinal arch:**
Shaded bones, on the medial view.

**Medial view.**

**Lateral longitudinal arch:**
Overemphasised bones on the lateral view.

**Lateral view.**

**Transverse arch:** Consist of the Cuboid and the 3 Cuneiforms

**Anterior view**
Movements of the foot.

The four major movements of the foot are:

- Plantarflexion.
- Dorsiflexion.
- Eversion.
- Inversion.

Plantar / Dorsiflexion: Occurs at the ankle joint, which is the articulation between Tibia and the Tarsal bones. The range of movement varies from between 50° to 90°.

**Plantar flexion.**

![Plantar flexion diagram](image)

**Dorsiflexion**

![Dorsiflexion diagram](image)
Eversion / Inversion: Occurs mainly at the Tarsal joints. The main movement happens at what is called the Transverse Tarsal joint. This joint consists of an articulation between Calcaneus and Cuboid, and an articulation between Talus and Navicular.

The movement at the Transverse Tarsal joint is a sort of rotation that results in slight flexion/extension of the foot where the sole at the same time is moved medially (inverted) or laterally (everted).

**Inversion.**

**Eversion.**
SECTION - 2

AMPUTATION OF

THE FOOT
LEVELS OF AMPUTATION

The levels of partial foot amputations are as listed below and shown in the picture:

1) Distal phalanx.

2) Disarticulation Proximal Inter Phalangeal joint. (hallux only)

3) Disarticulation of toes.

4) Distal metatarsals.

5) Proximal metatarsals.

6) Lisfranc (1815) - Tarsometatarsal disarticulation.

7) Chopart (1792) - Talonavicular + calcaneocuboid disarticulation.

8) Metatarsal / Phalangeal Ray.
CAUSES OF AMPUTATION

The most common reasons for this level of amputation are:

- Trauma (mines, motorbikes, burns etc.).
- Peripheral vascular disease (limited gangrene).
- Infection (very localized).
- Congenital deformities.

According to the type of countries we are working in, the main reasons for this type of amputation should vary. Most literature, when referring to this type of amputation are looking at it from the well industrialised countries. There, the main reason is vascular disease. Where ICRC is working, the main reason for this type of amputation is trauma, and the problems met with this cause differ from the precedent.

In many cases where ICRC is working, this amputation is on the so-called “sound side”. It means that usually, this is on the side that has been less affected by the trauma. The other side is often a below knee or an above knee amputated from a mine injury or shelling.
Advantages

- A full end bearing stump.
- Limited functional loss.
- Let the patient walk for short distances without a prosthesis.
- Proprioceptive properties of the sole of the foot are kept good in most cases.
- Relatively easy for patient to keep their balance especially on uneven ground.
- The usual psychological aspects of an amputation are probably reduced because of the limited loss of function and appearance.
- In the case of vascular operations where an amputation of the other limb can be expected at a later stage, it is an advantage to keep as much function as possible.

Inconveniences

- Poor wound healing, (when the reason for the amputation is one of poor peripheral blood supply).
- Distal skin cover must be from the plantar surface and with no tension, - for the more distal levels there are often problems with pain and contractures (e.g. varus equinus deformities).
- Bony overgrowths may become sharp and cause problems.
- The toe stump of a partial toe amputation often develops contractures in dorsiflexion.
- If toes disarticulation is performed of all or some toes, this will lead to more metatarsal head pressure.
- For the Chopart (performed between the proximal Talus / Calcaneus and the distal navicular and cuboid), the stump tends to be pulled into equinus by the unbalanced pull of the Achilles tendon if not overcome by fixation of Tibialis anterior and other extensors to Talus during the operation.
SECTION - 3

BIOMECHANICS
Before considering the biomechanics of the partial foot stump, it is important to understand the basic biomechanics-mechanical function of the normal foot during gait. This function can be divided into two main areas: - load bearing, and - joint function.

**Load bearing:**

The ground reaction force is transmitted to the body through the structure of the foot. During standing the longitudinal arch spreads the body weight so that 25% is carried by each Calcaneus and 25% of the body weight is carried by the Metatarsal heads of each foot.

During gait the force transmission has a different character relating to the phase of the gait, as described below:

**Heel strike**

The force is absorbed by the fatty tissue of the heel that is naturally adopted to absorb the high pressures.

Heel unloaded

Heel loaded
Foot flat towards push off

The supporting forces are shared between the heel and the ball of the foot. And to a very small extend by the lateral aspect of the middle part foot.

Push off

The force transmitted through the area of the Metatarsal Heads and the flesh of the toes is increased. The loads gets smaller as more weight is carried by the other leg. Eventually the load localizes on the plantar surface of Hallux.
**Joint function:**

The foot joints ability to alter shape and alignment is very important for the foot to adopt to different walking surfaces. Another very important action is the absorption of the longitudinal rotation of the lower limb, the nature of this is briefly described in the following.

At the beginning of stance phase the limb is rotating internally (rotation begins already in swing phase). The rotation is absorbed by a combination of movements (hind foot pronation and forefoot supination).

After foot flat the leg begins to rotate externally, and the rotational motions (pronation / supination) within the foot are reversed.

At heel off the limb continues external rotation, but the joints of the foot pronate to transfer the load onto the 1st Metatarsal head.

These complicated movements of the foot allow even distribution of pressure over the metatarsal heads and allow the foot to adopt to variations in walking surface.

Another important feature of the foot’s function is the relative flexibility during mid stance, and the stiffening via the intrinsic muscles and the plantar aponevrosis, that stabilizes the longitudinal arch and provides maximum rigidity of the foot for push off.
SECTION - 4

FUNCTIONAL LOSS

SPECIAL CONSIDERATIONS
FUNCTIONAL LOSS
and special considerations of the partial foot amputation.

The degree of functional loss of the foot will vary depending on the actual level of amputation, with the greatest loss at the more proximal level. The loss and the problems associated can be divided into different areas:

- Area of support.
- Weight bearing.
- Absorption of rotation.
- The stump.
- Muscle imbalances.
- Loss of active push off.
- Donning / Doffing.
- Length.

Area of support:

Many partial foot amputees will be able to walk for short distances without a prosthesis. But due to the reduced area of the sole of the foot there will be reduced balance as the area of support thereby also is reduced. The problem of balance becomes even bigger when a double sided amputation has been performed. See illustration below.
Weight bearing:

The normal weight bearing structure of the foot has been destroyed during the amputation as the plantar aponevrosis and plantar ligaments have been cut and the longitudinal arch thereby has flattened. This changes the force distribution along the sole of the foot.

With the majority of patients the weight should be carried through the end of the stump, it is important that pressure is distributed evenly along the full plantar aspect with reliefs for sensitive bony proeminences.

If end bearing is not possible some weight can be transmitted proximally at the patellar tendon area. This will however limit motion around existing joints, muscles will become weaker and there will be an increased risk of distal oedema.

Absorption of rotation:

The supination / pronation action of the foot designed to keep pressures evenly distributed over the metatarsal heads is lost. There is no effective prosthetic solution to this problem other than using a lateral wedge to ”throw” weight forward onto the region of the great toe so that contact is ensured during the last part of stance phase.
The stump:

Partial foot stumps will still have the fatty tissue that is covering the normal heel. The majority of the patients weight should be transmitted through this naturally adopted area.

The stumps will mostly have many bony prominences (e.g. lateral process of Calcaneal tuberosity) with thin skin cover that must not be exposed to high pressures otherwise callosities may develop.

The suture is in many cases adherent to the underlying bone and therefore also very sensitive to pressure or "rubbing" actions.

The dorsum of the foot has many tendons and blood vessels and is a relative sensitive area that only tolerates pressures distributed over larger surfaces.

The mid-foot amputations will further more have complications with an inversion position of the distal anterior part of the stump. See illustration below. This must to some degree be compensated for with a medial wedge.

A ) Transverse view of normal foot at Metatarsal heads.

B) Transverse view of Lisfranc amputated stump.

C) Compensation with a wedge.
**Muscle imbalance:**

As the amputation level becomes more proximal more muscles lose their insertions. The stump will end up with very strong plantar flexors that will tend to pull the calcaneus and the stump into a plantar flexion position and with strong inverters / supinators that will tend to pull the stump into an inversion / supination deformity. (See illustrations below)

Also because of the strong action of the plantar flexors the calcaneus will tend to migrate in posterior, so that the anterior section of the stump becomes much smaller and the calcaneus ”sticks” out in posterior and creates problems with cosmetic. (See illustrations below). This problem will become bigger as the level of amputation moves more proximal.

The plantar flexion and inversion deformity will give a functional longer leg, and will cause too high pressures at the lateral border and the end of the stump.

The deformities can often not be corrected entirely within a prosthesis so it is important that the surgeon understands the associated problems with this amputation level and tries to correct and avoid the problems during the operation.

![Posterior view of Chopart stump with deformities.](image)

![Lateral view of Lisfranc stump](image)

A - just after amputation.

B - after some time
**Loss of active push off:**

As the level of amputation moves proximal to the Metatarsal heads, the action of active push off is lost. This must be compensated for in the prosthesis so that some flexion is present at what was the Metatarsal-Phalangeal joint, (to avoid vaulting) and the prosthesis must provide some sole stiffness to give a rigid lever action of the forefoot during toe off.

**Donning/ Doffing:**

When an ”above ankle” prosthetic solution is used, the bulbous end of the stump will give problems with donning and doffing of the prosthesis. A solution that will not compromise cosmetic is to make a removable panel or to leave a panel section completely open.

In the case where a slipper type prosthesis is being used the problem will be to make the opening big enough to allow donning, yet not so big that suspension is lost. Other solutions may be to use flexible materials or to make a removable section.

**Length:**

The partial foot amputation has kept the full length of the normal leg. Therefore any addition to the length in form of a prosthetic device will have to be compensated for at the other leg.
SECTION - 5

PROSTHETIC SOLUTIONS

SOCKET DESIGN
PROSTHETIC SOLUTIONS / SOCKET DESIGN

The role of the prostheses will be to regain, as much as possible, the functional loss caused by the amputation. Always keeping in mind, the comfort, the cosmetic and the cost factor. The different types of partial foot amputations obviously require different types of prosthetic solutions.

Toe amputations:

It is true that the loss at this level of amputation can be considered largely cosmetic, and many patients can manage without any prosthetic aid. Adding some form of filling in the shoe, wool, cotton or foam, could very well do the job. But it must not be forgotten that even the sightless amputation in the foot creates an imbalance in the dynamic function of the foot. Your role as a prosthetist is not only to make the amputee comfortable, but also to avoid the long term complication that will emerge as time goes with any imbalance of the foot.

In many cases where ICRC is working, the toe amputations will be on the least affected side. It is often the “sound side”; the other side having been amputated, below or above the knee, after stepping on a mine or from shelling.

In the amputations where Hallux has been removed, there is a loss of the final component of push off during gait. There will be a tendency for the shoe to hyperextend at push off and the pressure at the first metatarsal head will be increased. Also there will be a tendency for the remaining toes to deviate towards the amputated side.

To avoid these problems the patient can be fitted with an insole that has a toe filler glued on to it. The insole must be stiff enough to provide some resistance to push off. There should also be some padding added under the head of the first metatarsal. In addition, a retrometatarsal pad is also a must to relieve efficiently the pressure under the head of the first metatarsal.

Toe filler

Plantar stiffener
One of the best ways of doing a proper job is to take a cast of the affected foot. This is a very efficient way to redistribute the load all over the sole of the foot, allowing you to relieve the sensitive areas, to load the less sensitive areas and to supply the foot with a good base for stability. To achieve the latest, you do need a good cupping of the heel. After having completed the corrections on the positive mould as for any prostheses, you can mould the insole on the mould. Finally you complete the build up on the insole.

Mould an Alvelux 6 mm over the plantar surface of the cast. Add some filling where required: the retro metatarsal area, under the head of the 1st metatarsal, the medial arch and the heel.

After, you grind the extra to prepare the insert before moulding the polypropylene (pp): flatten the heel to give a stable base.

Mould a 3 mm pp over the alvelux insole. An excellent way is to fix the pp in a metal frame before putting the piece in the oven and then using suction mould it over the alvelux fixed on the mould. Once cool off, you just trim and fit to the shoe.

If the patient is not amputated on the other side, you must supply him with a 6 mm insole, not moulded, to balance for the added height.
**Ray amputations**:

When only one of the 2nd to 4th rays have been removed, the patient can usually manage without any prosthetic help.

If however the 1st ray and / or more rays have been removed then it will mostly be necessary to make an insole that provides resistance to hyperextension and fills out the shoe thereby also keeping the remaining rays in the correct position in the shoe.

**Transmetatarsal amputations**:

The loss of load bearing surface is more severe at this level of amputation than in the toe amputation. And most patients will need some aid.

The problem with hyperextension of the shoe is more prominent than for the toe amputations and also there will be a tendency for the longitudinal arch of the foot to flatten.

The patient should be fitted with a shoe insert that is moulded accurately under the remaining area of the longitudinal arch, in order to support the arch and maximize the load bearing area. And to provide resistance to hyperextension during push off.

The insole should be built up in the anterior, in soft material to fill out the shoe and avoid uncomfortable shoe deformation.
At this level of amputation, the foot may have a tendency to slip off the shoe at the push off phase. An excellent solution could be a pair of laced boots. Unfortunately, it is not always available or affordable. For younger, basketball running shoes give the kind of support and anchor you do need. Also, because of its padded surfaces, it does allow you to spread the pressure over the dorsal surface of the foot.

Otherwise, given the material the ICRC uses, we can make the “slipper” type prostheses with opening on both side.

The advantages of this type of prostheses are:
- cosmetic;
- light weight;
- hold very well at the push off phase;
- does not require special, unavailable material. ICRC has all the material needed for its fabrication.
**Lisfranc and Chopart disarticulation:**

The prosthetic requirements for these types of amputation are much more demanding as it no longer is possible to depend on the patient's shoe to suspend the prosthetic device, it must be suspended to the remaining stump of the foot. There are two basic Biomechanics solutions. These are the "above ankle" and "below ankle" designs. Both will have to be made to a modified cast of the patient's stump, in order to gain a comfortable socket with total contact.
ABOVE ANKLE:

The above ankle solution is the most traditional. This solution used to be heavy and bulky especially when materials such as metal and leather were used. With the use of plastic materials the prosthesis becomes lighter and less bulky.

Also with the use of plastics it is possible to make prostheses that are based on an Ankle Foot Orthotic design. The materials may be thermoplastic such as polypropylene or thermoset such as laminated polyester or acrylic.

Today prostheses may be made to extend to just above the ankle, to the middle of the calf or to the patella tendon area. The height of the prosthesis will determine how much the ankle movement is limited.

All these types of prostheses will restrict the subtalar joint movement and thereby limit the possibilities for the leg to absorb the longitudinal rotation during gait, because of this and the reduced ankle movement the patient will have to adopt some compensatory movements.

Moments created during push off will be resisted by counter forces at the anterior proximal brim and at the heel. To minimize these moments the patients shoe may be fitted with a rocker sole and a cushion heel.

The specific indications for the above ankle solution are:

- When weight should be transmitted more proximally because of tissue problems in the distal weight bearing area.
- When it is desirable to reduce forces caused by moments created during push off.
- When motion around the ankle joint must be limited.
- When control of - for example - Calcaneus varus and equinus or other deformities is wanted.
Right: Patella tendon bearing prosthesis for transtarsal amputation.

Laminated. No movements at the ankle joint.

Left: Short posterior shell for Transmetatarsal amputation.

Laminated. Has a possibility for high anterior proximal pressure at push off.

Traditional solid ankle prosthesis (Symes).

Laminated and with metal side bars. Has no movements at the ankle joint. Is heavy and bulky.
Thermoformed AFO with toe filler or Transmetatarsal amputation. There may be some problems as the stump will tend to slide anterior, and when the orthosis is dorsiflexed. This can be minimized with a padded strap at the ankle.

For the Transmetatarsal and even the total toes disarticulation, this is an excellent solution. Basically, in term of cost efficiency versus the result obtain, this is one of the best solution for many partial foot amputation requiring an above ankle solution. It is very practical, easy to fabricate and very light. Good attention has to be paid to the moulding of the plantar aspect of the remaining part of the foot and for the padding added later to the distal end. The skin graphs, bony spur and bony structures which are not well padded, are often the cause of intolerable pain.
Polypropylene - orthotic design.

Anterior section of stump is built up in pelite, the anterior section of a SACH foot is attached and draped "into" the socket. Anterior opening, stump is held in place by spongiest alveolate polyethylene (alvelux) extending above the hard socket. The build up should be firm enough to keep it’s shape. It can also be covered proximally with a softer, more spongiest material like a neoprene or else.

Polypropylene - orthotic design.

Posterior section is open, a durable and flexible sole is attached to the plantar section of the socket, the foot is build up of spongiest alveolate polyethylene (alvelux) and covered with skin.
Orthotic design. Laminate with carbon fibre reinforcement.

For Chopart amputation. Stump is held firmly in place by removable anterior section. Some plantar / dorsal flexion is allowed due to the design.
**BELOW ANKLE:**

The slipper type solution has really been developed as new mouldable and flexible materials have become available. Only the stump is enclosed as the trim line finishes just below the ankle. The moments created between the stump and socket are resisted by an accurate fit around the Calcaneus.

There are 4 different designs depending on the materials used for the socket. These are:

- Rigid.
- Semi Rigid.
- Semi Flexible.
- Flexible.

In theory normal ankle and subtalar movements should be possible with a slipper design. The component of movement that is missing is the forefoot rotation. This can to some extend be achieved by wedging the forefoot laterally so that contact is maintained during the final phase of foot contact.

It must not be forgotten that the slipper will be insert in a shoe which does act as a reinforcing external support. The choice a proper solid shoe, if available, is an important asset, not to be neglected.

**RIGID / SEMI RIGID.**

The Rigid and Semi Rigid designs are generally laminated or thermoformed. With the lamination it is possible to achieve some flexibility by using flexible resins. The prostheses will generally be lined with foam (pelite or softer) to act as an interface between stump and socket so that high pressures are absorbed. The main problem with this prosthesis is the relative motion between the stump and socket which will cause breakdown of tissues.

**SEMI FLEXIBLE.**

There is a combination of materials used for this type of prosthesis but in general Utherane elastomers or silicone materials are used. Some designs use a rigid sole as the basis of the prosthesis; others require the development of a special fabrication tool for each patient.

The solutions are often named according to the name of the person who developed them or according to the name of the materials used.
FLEXIBLE.

This solution was originally designed to just provide good cosmetic solutions, but it has proven also to be effective for some patients in restoration of balance and more normal gait.

Mainly reinforced silicone materials are used for this solution. Usually the silicone is laminated into a cloth material that is reinforced with woven glass in the areas that need more durability.

Some form of springiness will have to be built into the prosthesis, by means of spring steel (or other material) attached to the bottom of the socket and extending to just before the anterior end.

Drawings of some different types of “below ankle solutions” can be seen on the following page.
The slipper types are made out of silicone, elastomer (synthetic rubber), flexible acrylic or polyester resin, mixed of flexible and rigid resin, thermoformed plastic such as polypropylene, polyethylene and copolymer.

Slipper type - "Bellman" design.

The stump is covered with pelite, (alvelux) that also is used for build ups to compensate for the inversion /plantar flexion position of the stump. Sole and heel are reinforced with glass and carbon fibres. Final prosthesis is covered with soft skin.

Colins partial foot prosthesis.

Silicone is laminated into a cloth material and reinforced with woven glass for durability. Spring steel is attached to the plantar surface of the socket.

Slipper-type Elastomer prosthesis.

(STEP)

Complexes manufacture process where individual custom made tools are developed for each patient. The materials are semi-flexible urethane elastomers.
Slipper prosthesis with a removable anterior keel to extend the socket proximal and to improve the suspension.

This slipper can be made out of polypro and alvelux, as well as other material. The inside of the boot is cushion with alvelux. As the amputee rolls over the foot during the push off phase, it does tighten on the stump and avoid the stump from slipping out. It doesn’t require any special material, it is aesthetic, light and functional. As a slipper type solution, this is one very acceptable for ICRC.
SECTION - 6

PATIENT ASSESSMENT
PATIENT ASSESSMENT

As with any amputee, the assessment of the patient with a partial foot amputations is very important. With so many variants of the amputation we will be faced with many choices, limited only by our experience and the material available to us.

Assessing the level.

It is not always easy to tell the exact level of the amputation. Palpation of the stump is often the only way to our disposal. The most accurate way would be to have an x-ray taken. This is not always possible. When it is clear at what level the amputation has occurred it is essential to refer to anatomy text books and determine the loss of function. Good knowledge of the anatomy of the foot is essential. If the amputation is at a distal level the function of the foot is obviously better than the proximal levels. This information will allow us to decide on the type of prosthesis required.

Skin Condition.

In many partial foot amputations the quality of the skin cover is poor, especially in the amputations at hind foot. It is often the case that well meaning surgeons will try to save a damaged foot and so ends up with inadequate skin cover.

The main difficulty is with scar tissue. It is thinner than normal skin and weaker. In the amputations at hind foot level there is often large areas of scarring. This must be noted and a prosthesis designed to adequately hold the foot and so reduced friction and pressure. Scar tissue is often adherent, that is, stuck to the underlying bone. It will be easily damaged. Callous formation is often seen in established patients. This indicates high usage but also can indicate poor fitting. In bad cases the callous may need to be removed. Always note it and make allowance in the rectification for the reduction in pressure or friction in that area. Hypersensitivity is often a problem. Thin skin cover and prominent bone structure can make the stump very sensitive to pressure. The entire stump must be carefully examined and all areas of sensitivity noted and marked.
**Stump alignment.**

It is essential to be fully aware of the overall alignment of the limb. If the patient has a mal aligned knee it will reflect on the final alignment of the forefoot.

The alignment of the foot in relation to the shin is also important. The range of movement and correction are to be observed and noted. The natural alignment should also be checked in load bearing. If the patient develops mal alignment when load bearing we must assess just how much the limb can be corrected and do so during casting and later in rectification. It is important to not over correct so the patient finds the pressure intolerable. If necessary mal alignments can be accommodated inside the socket and then compensated for in alignment of the prosthesis.

**The patient as a whole.**

Naturally the whole limb should be examined for function and strength as in all levels of amputation. Also close questioning should take place to establish the patients desires and expectations of the prosthesis. If expectations are wrong then the patient should be educated and encouraged.

**Prescription.**

With these simple facts in mind it should be possible to establish an accurate breakdown on loss of function, difficulties and patient expectations. This information together will allow the development of an adequate prescription.
SECTION - 7

CASTING

&

MEASUREMENTS
CASTING

In order to fabricate a prosthesis, you can take measurements, make the tracing and take a cast. The measurement and the tracing are two dimensional approaches. The casting is a three dimensions approach. Now it must be remembered that the residual amputated part of a limb is a three dimensions segment. Therefore, casting is an efficient way to obtain a volumetric duplication of the stump in order to fabricate a prosthesis according to sound biomechanics principles. The casting approach in the field of prostheses has been used for many decades and it is still the most popular way to fabricate custom made prostheses. It is the most economic and efficient way to obtain a three dimensions representation of the stump. Even today where we are using electronic means (CAD CAM) to obtain volumetric measurement of the stump and to fabricate prostheses, the casting approach is still the most commonly used.

The casting approach is based on two very distinct parts for the fabrication of the prostheses. The first part is the negative mould which is taken with plaster bandage, on the remaining of the amputated limb. The second part is the positive mould which is done by filling the negative mould with plaster of Paris. It is a replication of the stump.

The approaches to cast taking are very diversified. From the patient part, he can be laying down, sitting or standing while you are taking the cast. The angulation of his stump varies according to the kind of amputation and the approach the prosthetist is using. The weight bearing can be total, partial or none. His stump’s muscles can be contracted or relaxed.

From the prosthetist part, he can choose to lay the build up directly on the stump or to do it later on the positive. He can use a one step wrapping technic or a multi steps approach. The plaster bandage can be regular i.e. non stretchable or elastic. He can use a prefabricated brim or do everything with his hand. He can also, compress the mould directly on the stump, by means of an elastic bandage, a prefabricated compressing sleeve, or a vacuum.
All approaches have their advantages and their inconveniences. The build up on the stump is excellent if you are using the negative mould for a check socket. But it can move and then it is very difficult to locate the bony proeminences which must be relieved of pressure.

The one step casting is faster but it really demands from the prosthetist much skill to obtain an adequate mould that will give a good duplication of the stump, requiring little modification.

The use of a multi steps casting technic demands less skill for controlling adequately each particularity of the cast and can give a more accurate negative mould. But it requires more time to take and if use without any means of compression (elastic bandage, vacuum etc.), it gives a negative mould bigger than the stump.

The best casting technic is the one that will give the best socket while requiring the minimum work from the prosthetist, for the modification as well as for the fitting of the protheses.

**MEASUREMENTS**

The measurements are a two dimensions reference used to control a three dimensions model. The measurements used in prosthetic are linears and angular. They are:

- circumferences, with or without tension;
- diameters, medio lateral and anteroposterior, with or without compression;
- length and height.
- angulation of contractures and so on.

To avoid discrepancy between the cast and the measurements, you should take the measurements in the same position and the same load bearing as the cast is going to be taken. Make sure the stocking net is well tense and won’t move while taking the measurements or the cast.
CASTING & MEASUREMENTS PROCEDURE
( above ankle design)

1) The equipment required for the casting :

- Callipers
- Indelible pen.
- Stocking net.
- Knife.
- Tape measure.
- Measurement chart.
- Cutting tube or strap (alvelux 6 or 12 mm.).
- Plaster of Paris bandage.
- Cast cutter.
- Water.
- Thick alvelux - To distribute weight.
- Heel wedge. - To compensate for shoe heel height or stump equinus.

2) Secondly a careful assessment is made of the patient. Together with a small interview regarding personal data and other factors that may affect the choice of prosthesis. Some of the relevant areas to look at are:

- Should the patient have a prosthesis with full end bearing ?
- How is the condition of joints, are there any muscle contractions ?
- Are there any joint deformities; can they be corrected?
- How is the condition of the stump with regards to scars, bony proeminences etc. ?

The patient assessment procedure is described in more detail in the chapter of this book named - ” Patient assessment ”. All relevant details should be recorded in the patient measurement chart.

3) A stockinet ”sock ” is applied to the stump ( must be slightly wet for markings) and, if require, the padding for cutting is put under it. The padding should be placed so that it interferes the least with future rectification.
4) The stump marks needed are as follows:
   - Lower border of head of fibula.
   - Medial tibial flare.
   - Lateral + medial malleoli.
   - Tuberosity of navicular.
   - Scars, bony proeminences etc.
   - Tibial crest.
   - Shaft of fibula.
   - Calcaneal tuberosity.
   - Head of 5th Metatarsal.

5) Take the measurements. The relevant measurements are the following:

   - Stump circumferences at level of -
     Stump (for Chopart)
     Malleolus.
     Smallest area above ankle.
     Biggest area at calf.
     Top of prosthesis.

   - Medio - Lateral diameter at -
     Calcaneus.
     Malleolus.
     Smallest area above ankle.

   - The height from the floor to where circumferences and diameters have been taken.
   - Length of normal foot.
   - Heel height of patient's shoe.

All measurements are recorded carefully on the sheet provided.
6) Plaster is applied to the stump. First the distal end is wrapped with plaster bandage to about the level just above the Malleolus. Here after one of two procedures is chosen.

A) Patients that will have full weight bearing in the prosthesis and who can stand during the casting session. After wrapping the distal end the patient stands on a layer of alvelux and a heel wedge if it is needed to compensate for shoe heel height or stump equinus position. Care must be taken that the calcaneus is held in a neutral position if this is possible.
B) Patients who will not have full end bearing or cannot stand during the casting session or if a non load bearing situation is needed to correct Calcaneal varus. After the distal end has been wrapped in plaster the prosthetist forms the distal end with the hands. Again it is very important to make sure that the Calcaneus is in neutral position, and that the stump is in the required dorsi / plantar flexion position.

7) The proximal part of the stump is wrapped in plaster to the level of the Fibular head.

The prosthetist must form the lateral and medial aspects at the area of the medial flare and the Tibialis anterior muscle to create a triangular shape that will help unload the tibial crest.

8) Finally plumb lines are made on the cast in posterior and laterally with the patient standing in a natural position. This is essential for the bench alignment procedure. The cast is cross marked and cut off.

9) After the patient has been taken care of with regards to cleaning, a new appointment etc. the prosthetist can seal and fill the cast with plaster so it is ready for rectification.
SECTION - 8

RECTIFICATION OF

THE POSITIVE MOULD


**RECTIFICATION PROCEDURE**

*(above ankle design)*

The aim of rectifying the partial foot cast is exactly the same as for all other casts, namely to create a model over which a good socket, based on proper biomechanics concept, can be fabricated. The procedure is as follows:

1) Before the cast is stripped the plumb lines should be transferred onto the positive cast.

2) When the cast has been stripped it is tidied, smoothed and all markings are redrawn, including the plumb line.

3) All stump measurements are checked on the cast, compared with the measurement chart and goals are set.

4) If the Calcaneus can be corrected more than the cast shows, it should be rectified at this point.

The rectification is done by first measuring and writing down the diameter of the calcaneus and then removing material at the medial aspect (in case of varus position) and thereafter adding material at the lateral aspect.

When doing this it is important to keep the diameter the same and not to correct more than what is possible in the non load bearing situation. If too much rectification must be done, it would be better to retake a negative mould.

5) Reduction of the cast is limited as the amount of soft tissue often is minimal. The general areas to look at are:
- Usually the circumference at the proximal part of the cast should be reduced a little, how much will depend on the amount of tissue and its firmness.
- The area of the Tibialis Anterior muscle and the medial flare should be slightly flattened, to help unload the tibial crest.

- The lateral and medial aspect of the Calcaneus should be smoothed with great care, the aim is a firm grip that is not painful.

- The plantar surface should mostly be flattened especially when the cast has been taken without weight bearing. The amount will depend on how much distal weight bearing is desired.
When flattening the plantar surface special care must be taken not to reduce any areas with bony proeminences that do not tolerate pressure.

6) The build ups of the cast are as follows:

- Mostly a moderate build up is needed at the stump end around the area of the suture line.
- The base of the 5 Th. Metatarsal should have a small build up of approximately 2 mm. (for amputations more distal than tarsometatarsal level).

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- When the Tuberosity of Navicular is prominent it also should be built up.
- Any bony proeminences that are sensitive to pressure at the plantar surface should have a build up.

- Around the distal edge of the cast a small build up must be made to allow for some compression of the soft heel pad. The amount will depend on whether the cast has been taken in weight bearing.

- The Calcaneal tuberosity and the Achilles tendon must be built up to avoid pressures.

- Both the medial and lateral Malleolus should be built up with 2 - 3 mm at the top point.

- Distally, the shaft of fibula will be prominent and needs a build up.

- The Tibial crest must be build up in a similar manner when rectifying a Below knee prosthesis cast.

- At the proximal trim line a small built up can be made to create a flare of the socket.

7) After all reductions and build ups have been completed the cast is smoothed and assessed. Is the position of the stump correct? Does measurements of the cast correspond to measurements of the patient? - etc.

One very important factor to keep remembering is that the areas of the stump that can tolerate pressure are very small therefore it is important to keep all the build ups very localized.
REFERENCES


3. Traité d’Anatomie Artistique, Dr. Paul Richer, Inter-Livres

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