ORTHOLETTER

A NEWSLETTER ON ORTHOPAEDIC TECHNOLOGY IN DEVELOPING COUNTRIES

Number 5

In this issue:

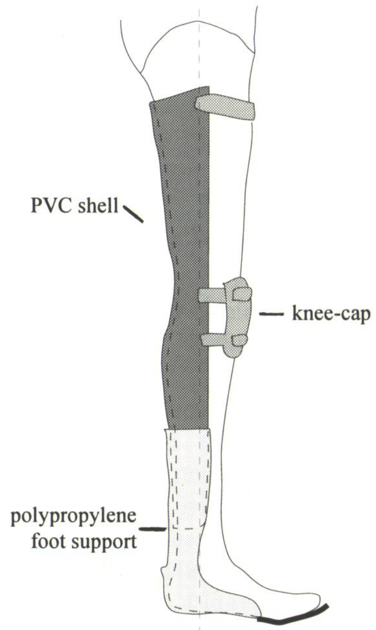
Thermoplastic technology:

Low-cost PVC/polypropylene orthosis

In Pondicherry, India, low-cost calipers for polio children are manufactured in thermoplastic materials. PVC shells and polypropylene foot supports are prefabricated and adjusted to the child's leg at the time of fitting. To avoid long prescription processes and the risk of the child developing contractures, Multipurpose Rehabilitation Technicians with knowledge of physiotherapy have been introduced. .... **page 2**

Lower limb prostheses for all levels of amputation

In Lokichokio, Kenya, polypropylene prostheses are produced for all levels of amputation. .... **page 6**

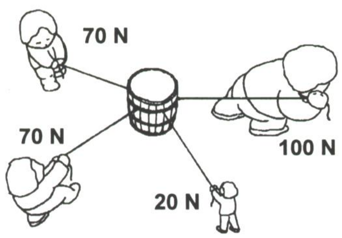


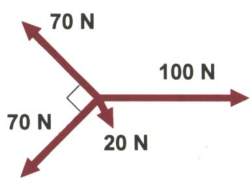
The PVC/polypropylene orthosis

Biomechanics in Prosthetics and Orthotics (3)

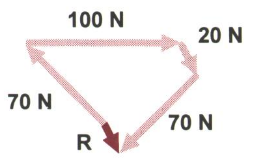
In this part of *Biomechanics in Prosthetics and Orthotics*, the *second condition for equilibrium* will be introduced. Before that, however, we will have to learn what is a *moment of force*. ....**page 7**

Solution to the mechanics problem presented in the last issue:

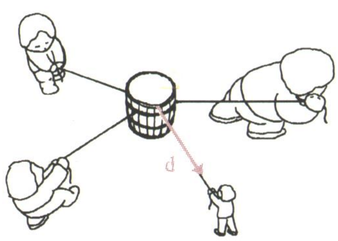




The forces as seen from above (Scale: 1 cm = 50 N)



Finding the resultant with the polygon method. (R = 20 N)



Clarification: To know in which direction the barrel will move, we have to determine the resultant of the four forces. (The *resultant* is the simplest force that can produce the same effect on the object as all the forces acting together.) To do this, the polygon method is used. The outcome may be a little surprising because we find that the resultant has the same direction and magnitude (20 N) as the force produced by the *smallest* boy (!), which means that the barrel will move in his direction (d). In fact, if it was not for him, the barrel would not move at all since the other three forces completely neutralise each other (their resultant is zero).

Next issue:

Community Based Rehabilitation (CBR) - an introduction

Educational Training in Cambodia

Low-cost PVC/polypropylene orthosis

At the orthopaedic workshop of Rehabilitation of the Disabled in India, RDI, a cost effective technology has been developed for the manufacturing of PVC/polypropylene orthoses for children with polio. The caliper makers have basic knowledge of physiotherapy, which enables them to take complete care of the rehabilitation in areas where no expert teams are available.

For children affected by poliomyelitis, provision of an appliance is almost always a therapeutic emergency. Due to lack of proper and early care, many of them will quickly develop contractures and other deformities, which will make the rehabilitation more difficult.

The complicated procedure for prescribing orthotic appliances is often one of the reasons why contractures occur and orthoses are rejected among children with disabilities. The usual prescription procedure is that the patient has to be assessed by a physiotherapist who tests the muscle power. A specialist in orthopaedic surgery will then be consulted to decide which type of appliance the person needs and only after that can the caliper be made at the orthopaedic workshop. This procedure is very time-consuming and contractures may unnecessarily develop while the child is waiting for the orthosis. Furthermore, the decisions concerning the fitting are often taken by looking at the results of muscular testing only, without considering the functional abilities of the child. The disabled person's point of view and feelings regarding what they need are seldom looked at by the deciding professionals, the patient often being considered a medical case rather than a person.

A new rehabilitation concept

The idea of Rehabilitation of the Disabled in India, RDI, which is an organisation representing Handicap International in Pondicherry, is that the choice of appliance may very well be made directly by orthopaedic technicians, if only they have basic knowledge of manual physiotherapy. This will make the prescription process considerably shorter. In line with this view, Handicap International decided to establish training courses for **Multipurpose Rehabilitation Technicians** who can act as technicians for plastic calipers as well as physical therapy assistants and animators. These technicians, working at field level, have the knowledge and skills required to decide on therapy and fittings for most of their clients, without depending on the usual team composed of a physiotherapist, an orthopaedic surgeon and an orthotist, which is seldom available in the field. The role of the technician includes a whole range of actions intended to organise the physical rehabilitation of a child with polio, i.e. to assess the needs of the child, to choose and produce the appropriate appliance, to train the child in the use of the appliance and to organise technical and medical follow-up.

Furthermore, and just as important, the Multipurpose Rehabilitation Technician should establish contacts with the parents of the child and make sure that they and the child itself are actively involved in the rehabilitation, also when the choice of orthosis is made. This will make the appliances less likely to be rejected.

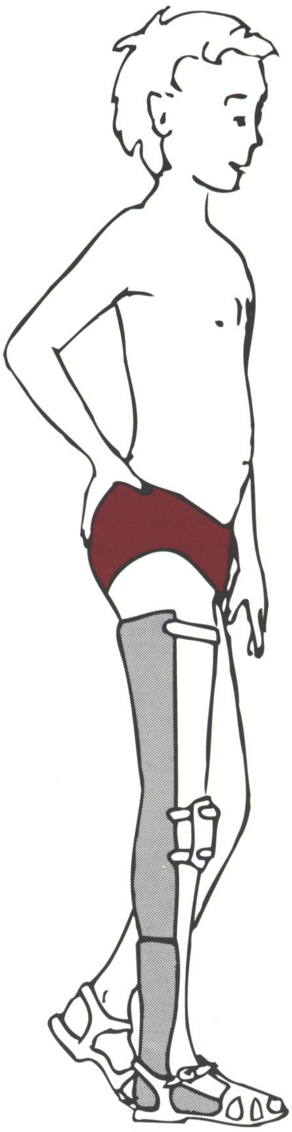


Figure 1. The plastic caliper made in Pondicherry consists of a PVC shell and a polypropylene foot support.

A balanced choice of technology

For many children affected by poliomyelitis, calipers are necessary to *prevent deformities*. However, the appliances should also improve, or at least preserve the children's ability to *move*. The prescription must be a balanced choice between the possibilities of functional improvement and the requirements of prevention, keeping in mind that the appliance should not restrict movements unnecessarily and should be as light as possible. In this respect, the traditional caliper (made of heavy steel and connected to heavy ankle boots) has not been very successful, except when used by strong adults. A plastic technology developed in Pondicherry, however, allows a better response to the requirements, and hence the caliper is more easily accepted by children with disabilities (figure 1).

The plastic technology

In Senegal in 1984, a Swiss organisation, Terre des Hommes, developed a technique using PVC and polypropylene to manufacture orthoses from prefabricated modules. The modules were moulded on standard aluminium patterns. This technique was adapted to the Indian context in 1988 by the French organisation Handicap International. The main modification was to use wooden moulds, which were traced from paper patterns based on measurements from children, instead of using standardised aluminium moulds.

The caliper which is produced in Pondicherry is still made of the same two thermoplastic materials, i.e. rigid **PVC**, which is a material that is also used in drain pipes, thus often available in developing countries, and **polypropylene**, a flexible plastic which normally has to be imported in industrial sheets.

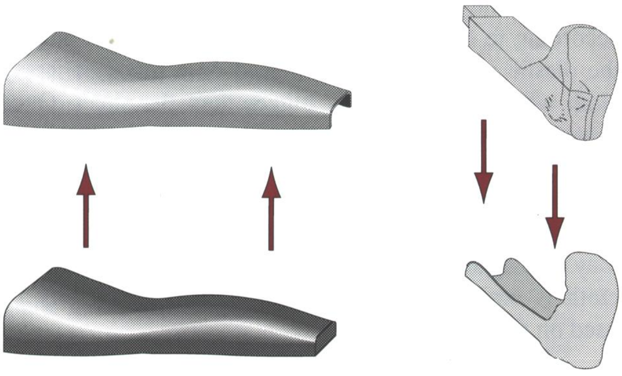


Figure 2. The PVC shell and the polypropylene foot support are manufactured on wooden moulds

The fitting

The plastic caliper consists of two major parts: a PVC shell which supports the leg and a polypropylene foot support which holds the foot. These two parts are manufactured in advance on wooden moulds (figure 2). At the workshop of RDI in Pondicherry, a permanent stock has been set up of standard modules in various sizes. When the patient is to be fitted, a PVC shell and a foot support are selected from the store according to the size of the patient's leg. The modules are then adjusted according to the limb (if this is found necessary) and riveted together. Finally, a knee cap and thigh strap of leather are attached (figure 3). When fitted in a correct way, the caliper provides full support to the thigh and to the foot. This support is sufficient to stabilise the limb. In the overlapping zone, however, the caliper should not be in contact with the skin (figure 4). The caliper can be worn with an ordinary plastic, leather or tyre and tube sandal, or with most types of ordinary shoes.

Even though it was initially designed for children, this plastic caliper technology also fits the requirements of adults. The strength of the foot support can be increased by using thicker polypropylene sheets. PVC of about 4 mm thickness is strong enough for the leg shells for all users.

Appropriateness to rural context

The plastic caliper is well suited to the orthopaedic requirements for prevention, functional adaptation and in some cases correction of deformities. Furthermore, the developed technology allows the provision of service to children with disabilities living in rural areas. The fitting work does not require any advanced tools but can be done in small, simply furnished *assembling workshops*. Prefabricated components can be delivered by a centrally based workshop which is equipped with an oven. The caliper itself takes only a short time to manufacture, which means that the patient can be fitted the same day as he/she arrives. This is very important for people who have travelled a long way to the workshop and who can only be away from their home a limited time. Another advan-

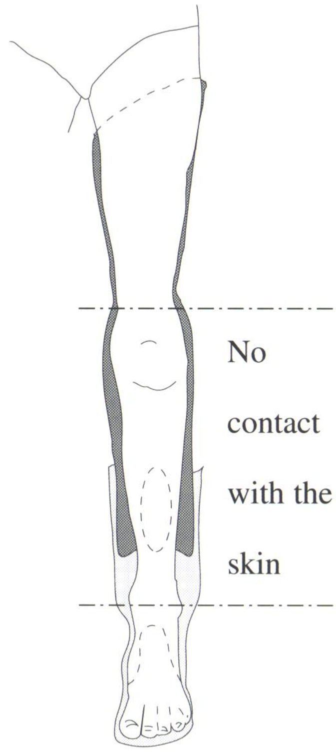


Figure 4. The caliper is in contact with the leg all along the thigh and at the foot. Between the knee-holding and the heel-holding points, however, there is no contact with the skin

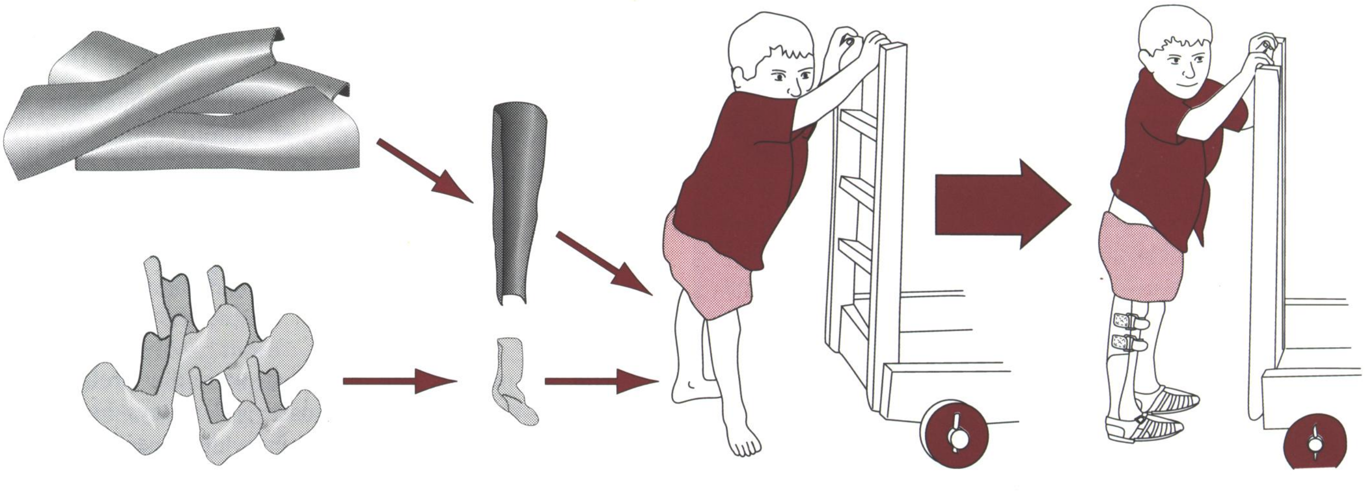


Figure 3. The modules are selected from the store, adjusted to the leg of the child and riveted together.

tage is that this orthosis costs only one third as much as a conventional caliper, allowing three times as many to be produced for the same budget. Last, but not least important, due to its light weight and the fact that it may be worn with any type of shoe, it is appreciated among children.

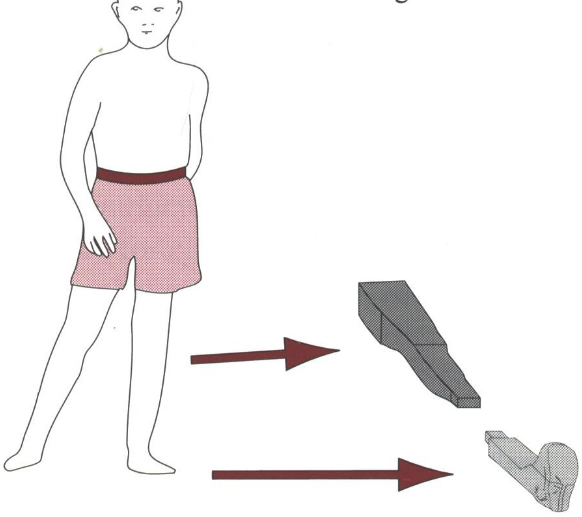
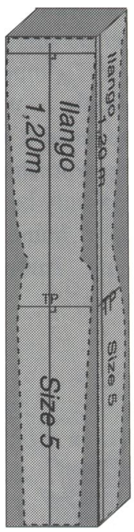


Figure 5. The standardised wooden moulds are made according to measurements from children.

The manufacture of wooden moulds

The production of plastic modules requires two types of wooden mould: leg moulds for the production of PVC shells and foot moulds for the production of polypropylene foot supports. To manufacture the moulds, children's legs are used as models (figure 5). The children's heights should range from approximately 70 to 140 cm. The legs should be fairly thin, but without any deformity (not suffering from the after-effects of poliomyelitis). The outlines of leg and foot are drawn on paper fixed to a board, taking front and side views. From these drawings, patterns are made according to certain principles and then transferred to wooden blocks for cutting (figure 6). Usually, 5 to 6 different sizes of moulds are necessary to be able to produce calipers for children in the age group 1 - 14 years.



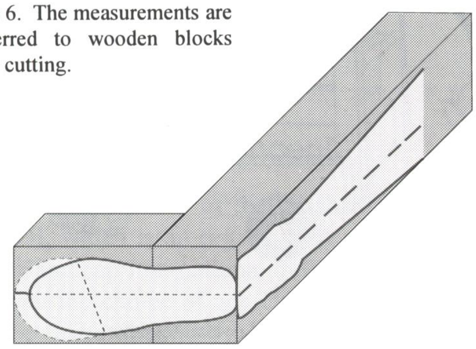


Figure 6. The measurements are transferred to wooden blocks before cutting.

The moulding

Moulding is done with an oven of minimum internal dimensions 100 x 45 x 40 cm, capable of heating to 170 °C to treat the polypropylene. (PVC should only be heated to approximately 120 °C.)

To mould the *foot support*, a polypropylene sheet is cut according to the dimension of the mould. When putting the plastic in the oven, it is placed on a piece of jersey cloth which is cut slightly bigger than the sheet. Once heated, the sheet is placed on the mould, starting from the heel and making sure that the material is stretched over the malleoli just enough to avoid wrinkles over this area (figure 7). (To facilitate the moulding process, it may also be made under vacuum. In this case the jersey cloth is omitted. Instead, a cotton stockinette may be used on the mould.)

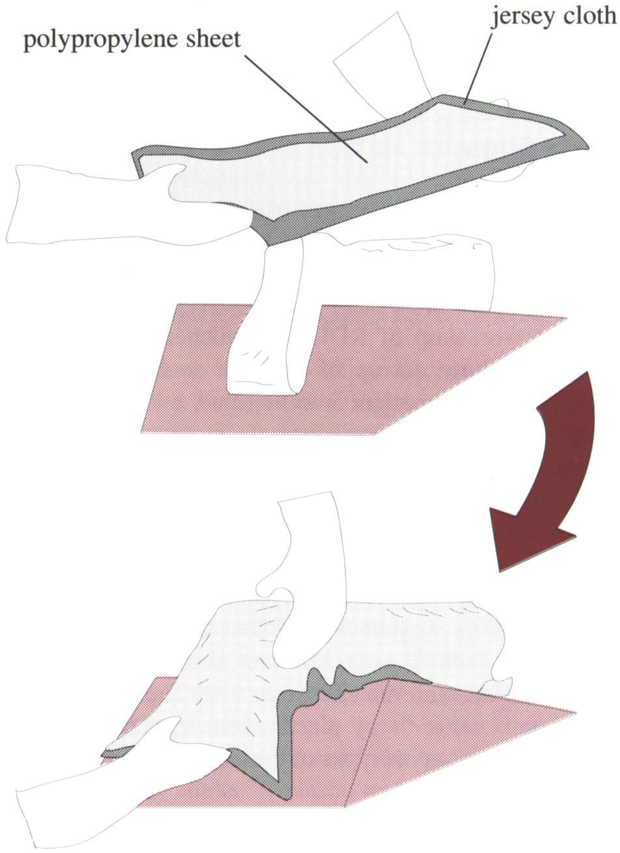


Figure 7. The polypropylene plastic is moulded on the wooden mould.

To mould the *PVC shell*, the mould measurements are reproduced onto a PVC pipe before cutting it. The moulding is made in a specially designed shell-moulding press.

Different types of orthoses and their application

Not all patients can be fitted with the prefabricated module caliper; some orthoses will always have to be manufactured according to individual needs. Various kinds of lower limb thermoplastic orthoses are produced at the RDI orthopaedic workshop in Pondicherry. The most common are briefly described below:

The **supple foot support** (figure 8) is used when the foot has a mobile equinus (dropfoot) which needs to be corrected, but when there is no major instability or deformity in the ankle and foot. The degree of suppleness of the foot support depends on the way it is cut at the ankle level.

The **rigid foot support** (figure 9) is basically made in the same way as the supple one, but it allows little or no dorsiflexion at all. This foot support is prescribed when the foot or ankle is very weak and/or painful and may become deformed by the pressure of weight-bearing. The appliance must therefore be strong enough to maintain the foot and ankle in a good position. It may also be necessary to pad the inside of the foot support with soft material when the foot has a flattened or over-high arch, or when the heel has a sideways deformity, so as to give the foot/ankle a good position and better distribute the pressure of weight-bearing.

The **standard long caliper** (as already described) is advised for patients with weak knee, ankle and foot, but who still have a stable hip.

The **extended caliper** (figure 10) is proposed when the child has a weak or overstretched hip. It provides more stability to the hips, without reducing weight-bearing on legs. In this way, the normal bone growth is not impaired.

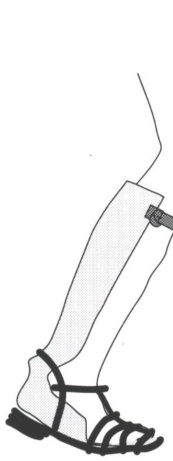


Figure 8. A supple foot support. The more you enlarge the cutting out behind the malleoli, the more you allow dorsiflexion.

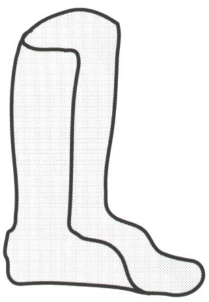


Figure 9. A rigid foot support. By keeping the sides of the foot support, you prevent the foot from turning sideways. The length of the sides must stop before the first bone of the toes.

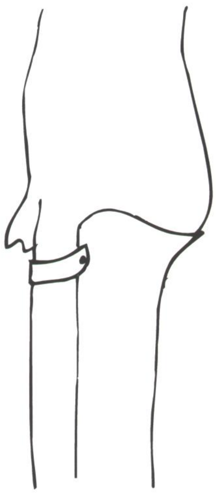


Figure 10. The shell of the extended caliper is prolonged proximally to provide stability to the hip.

The **long caliper with ischial support**, or seat caliper, is meant for a very unstable hip. When the hip joint is easily or fully dislocated (figure 11), it is necessary to reduce the weight-bearing which would otherwise worsen the problem. In order to achieve this, the upper part of the PVC shell is shaped like a seat (like in the socket of an above knee prosthesis) so that the child can sit on it while in a standing position (figure 12).

All these types of long caliper can be manufactured with or without hinges to allow the bending of the knee. For a young child who is learning to walk with an appliance, the knee joint is normally not recommended as children initially adapt more easily to the simplest and lightest models. If knee hinges are used, they can be designed locally or bought separately according to the needs and the available funds; their strength depends on the quality of the metal and on the way they are manufactured. □

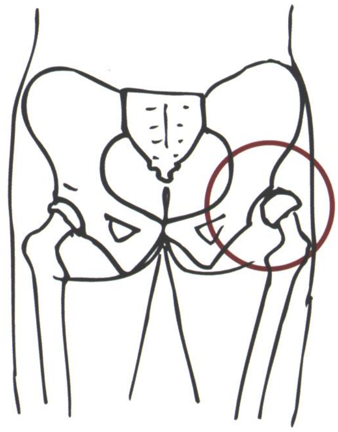


Figure 11. A dislocated hip will not support the full weight-bearing.

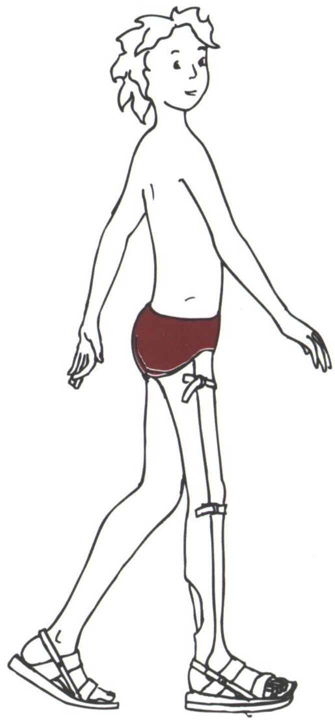


Figure 12. The long caliper with ischial support.

The book 'A Plastic Caliper For Children', published in 1994 by Handicap International, explains the details of the developed technology.
The video film 'Rajamutthu' is also available in English, French and Tamil. It shows the different steps in the physical rehabilitation of a child with polio.
For further information about this plastic caliper technology and the training courses, please contact:

Handicap International
14, Avenue Berthelot
F-69361 LYON CEDEX 07
France

Phone:
+33 78 69 79 79
Fax:
+33 78 69 79 94

Further development of PP-technology:

Lower limb prostheses for all levels of amputation

We received a letter from Julius Angoya Otieno, an orthopaedic technologist at a limb fitting centre in Kenya. After reading an article in the third issue of ORTHOLETTER (1 - 94) about the production of polypropylene prostheses, he felt that he wanted to tell us about the development work that has been made at his workshop. With the assistance of the International Committee of the Red Cross, ICRC, methods have been elaborated for the production of partial foot, through knee and hip disarticulation prostheses, all using polypropylene (PP). This is what he wrote:

" Our orthopaedic workshop is located in north western Kenya near the Sudanese border in a small town named Lokichokio. The centre is integrated within an ICRC surgical facility known as Lopiding Surgical Hospital for War Wounded, which is part of a humanitarian operation focused on the conflict in southern Sudan. The activities started in the year 1992 and the centre is currently operating with fifteen persons, among them one German Orthopaedic Master who is in charge of coordination and supervision of all activities. The local staff is composed of one orthopaedic technologist (trained at TATCOT in Tanzania) and on the spot trained assistants.

Most of our patients are lower limb amputees. All levels of amputation are fitted, including partial foot amputations, below knee, knee disarticulations, above knee and hip disarticulations. The entire process of design, manufacture and fitting is made on the spot, as are the components.

For the first part of 1995, an average of fifty prostheses per month were produced. In addition, twenty *orthotic* devices were fitted to in- and out-patients. A production of simple iron crutches is assured by two welders. The crutches are used by the in-patients during their stay in the hospital and some are sent to various accessible places in southern Sudan. Also a small amount of walking frames are produced.

Technology

The prosthetic technology presently in use at our workshop is basically the one reported in ORTHOLETTER 1 - 94. Because of the advantages of thermoplastic materials in comparison with polyester resin (these advantages were clearly outlined in the article), we are trying to implement a wide use of polypropylene. After having read the article, we realised that certain processes are under way in our workshop that did not appear in the text. Apart from being able to produce our sockets, alignment devices and knee components, we are also producing our feet out of polypropylene. In addition to those prostheses mentioned in your article, we do as well fit hip disarticulation (figure 1), knee disarticulation (figure 2) and partial foot prostheses (figure 3), all in polypropylene.

Figure 1. Hip disarticulation prosthesis in polypropylene.

Figure 2. Knee disarticulation prosthesis in polypropylene.

The mechanical single axis joints are designed and manufactured locally, adapting the European designs for mechanical foot, knee and hip articulations and using mild steel pipes and plates in the production. A single axis foot in polypropylene has proved to be successful for the fitting of bilateral above knee amputees.

All prostheses produced at our centre undergo the same basic procedure; a negative is made of plaster-of-Paris, followed by a positive which is rectified according to basic biomechanical principles for each level. After the rectification is completed, the positive is ready for moulding with polypropylene, a process which corresponds to the one described in your article. Concerning the fitting of below knee amputations, we produce soft sockets for very short or bony stumps, stumps of old patients with loose skin and for some women and children. However, patients with normal medium or long stumps do very well with hard polypropylene sockets. ❞

For further information about polypropylene technology, training courses in Addis Ababa and the procurement of aluminium moulds, please contact:

ICRC - Orthopaedic Projects
Medical Department
19, Avenue de la Paix
CH-1202 Geneva
Switzerland

Phone:
+41 22 734 60 01

Fax:
+41 22 733 20 57

Figure 3. Partial foot prosthesis in polypropylene.

If you too have any experiences from your workshop that you would like to share with other readers, please write to:

ORTHOLETTER
IBO, Box 1038,
S-551 11 Jönköping
Sweden.

Biomechanics in Prosthetics and Orthotics (3)

Moment of force

If two boys of equal weight are to balance one another on a see-saw, they must sit at the same distance from the centre of the board (figure 1). However, if an *adult* wishes to balance with a boy, the boy will have to sit further from the centre than the adult. If the boy's weight is half that of the adult, the boy will have to sit twice as far from the centre. If his weight is only one third, he will have to sit three times as far back, and so on (figure 2). The weight of a person sitting on a see-saw has a turning effect on the see-saw board - it tends to rotate it. As we could see in the examples above, the magnitude of the turning effect depends on two factors; the size of the force (a heavy person tends to turn the board more than a light one) and the distance from the force to the turning point (the further from the centre the person sits, the higher the turning effect). In mechanics, the turning effect is usually referred to as the **moment of force** or simply the **moment**. The moment of force may be calculated by multiplying the *force* by the (perpendicular) *distance* from the force to the turning point. This is usually written M = F x d (where 'M' is the moment, 'F' the force and 'd' the distance) (figure 3). The moment is usually said to be positive when it has a clockwise turning effect and negative when the effect is directed counter-clockwise (figure 4). Since a moment of force is the product of a force and a distance, the SI unit of moments is the Nm (newton-metre). On the far right are three examples of how moments of force may be calculated.

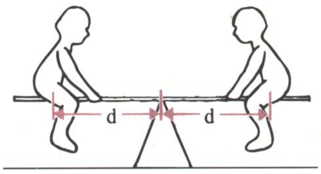


Figure 1. To balance each other, two boys of equal weight must sit at the same distance (d) from the centre.

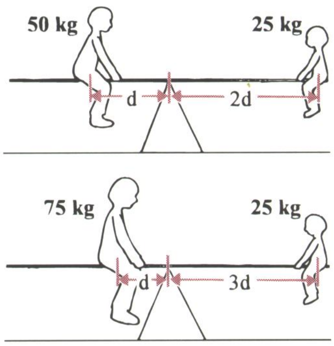


Figure 2. The boy must sit further from the centre to balance an adult.

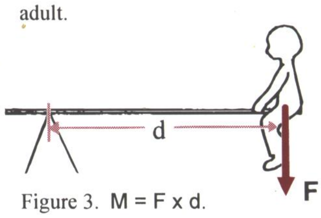


Figure 3. M = F x d.

Figure 4. The force F_1 has a *clockwise* turning effect on the board. Such a moment is usually said to be positive. The turning effect of F_2 is directed *counter-clockwise* and, correspondingly, the moment is said to be negative.

Example 1: A boy is balancing a small sack on a stick (figure 5). What is the moment of force exerted by the sack about the shoulder of the boy? (The shoulder is the turning point of the stick.)

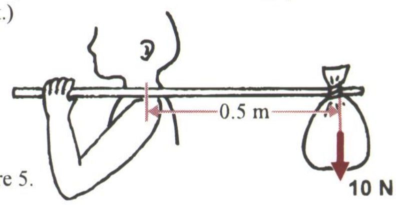


Figure 5.

M = F x d = 10 x 0.5 = 5

The moment of force is 5 Nm.

Example 2: A lady is carrying a bag on her forearm (figure 6). What is the moment of force exerted by the bag about the elbow? (The elbow joint is the turning point of the forearm).

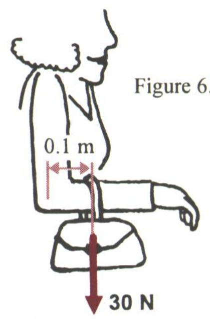


Figure 6.

M = F x d = 30 x 0.1 = 3

The moment of force is 3 Nm.

Example 3: What would be the moment of force if the lady in the previous example was carrying the bag in her hand instead of on her forearm (figure 7)? (The elbow joint is still the turning point).

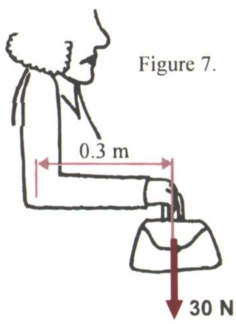


Figure 7.

M = F x d = 30 x 0.3 = 9

The moment of force is 9 Nm.

Note that in the third example, the moment of force is three times as high as in the previous one. This is because the distance is three times as great. (The result corresponds very well to our everyday experience; with a bent arm, it feels heavier to carry an object in the hand than on the forearm close to the elbow.)

Second condition for equilibrium

We have previously been introduced to the *first condition for equilibrium*, which states that if an object is at rest, the sum of the forces acting on it must be equal to zero **($\Sigma F = 0$)**. There are situations, however, where an object may not be at rest though the first condition of equilibrium is fulfilled. Let us, for example, make the following experiment; put ORTHOLETTER on a table in front of you. Grasp the upper right corner of the newsletter with your right hand and the lower left corner with your left hand (figure 8). Then pull the corners straight to the sides, i.e. to the right side with your right hand and to the left with your left hand, using the same force in both directions (figure 9). Though the forces are equal in magnitude and opposite in direction (meaning that $\Sigma F = 0$), the object is obviously not any more in equilibrium but tends to rotate (figure 10). Apparently, the first condition alone is not enough to describe the state of equilibrium but there is also need for a second condition.

The *second condition for equilibrium* states that if an object is at rest, the sum of the *moments* acting on the object must be equal to zero:

$$\Sigma M = 0$$

The sum of the moments of force may be determined about *any chosen point*; if the sum is zero about one point it is bound to be zero about any other point.

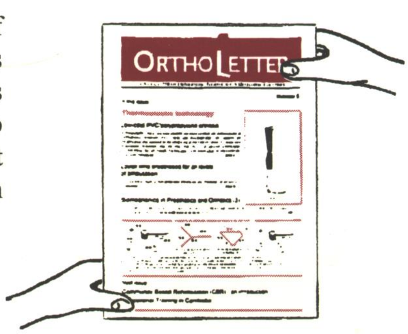


Figure 8. Hold the upper right corner of the newsletter with your right hand and the lower left corner with your left hand.

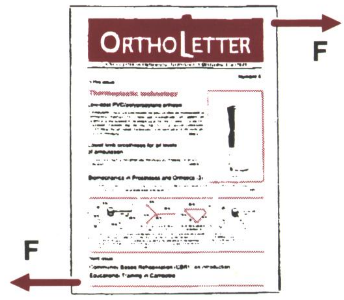


Figure 9. Pull the corners straight to the sides, using the same force (F) in both directions.

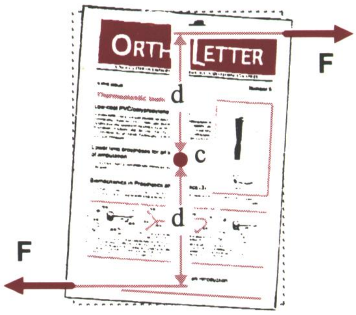


Figure 10. The forces, since parallel and not acting along the same line, produce two equal moments ($M = F \times d$), both of which rotate the object clockwise about its centre (c). Though the first condition for equilibrium is fulfilled, the object is not at rest.

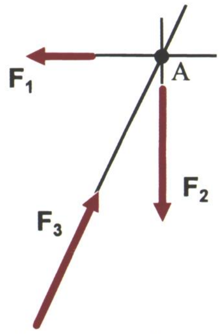


Figure 11. A concurrent force system. Since the forces are all acting through the same point (A), none of them will produce a moment about this particular point (d = 0 for all forces).

We may, finally, refer to the problem that was solved in the last section on *Biomechanics in Prosthetics and Orthotics* and the statement that the second condition for equilibrium would not have influenced the solution of that particular problem since the forces that were acting on the tug-of-war competitor formed a *concurrent force system*. Now we know enough mechanics to see why that is so; according to the definition of a concurrent force system, all forces are acting through the same point. If we choose this particular point (the point of intersection) as turning point, the distance to the point will be zero for all forces (d = 0). Then no one force will produce a turning moment around the point (figure 11). Consequently, the sum of the moments will be equal to zero and the condition fulfilled. (This is also true of *linear force systems* since they, in fact, are special cases of a concurrent force system; forces acting through the same line may also be said to act through the same point.)

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