Possibilities of Technical Orthotic Aid for the Paralyzed Lower Extremity *

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[Translated by SIEGFRIED W. PAUL, C.P.O.]

The orthotic profession is facing an especially difficult task in bracing of the paralyzed lower extremity. Difficult, because an appropriate application of the appliance must be based on the specific and individual design of the orthosis.

Orthotic appliances for the paralyzed looked very much alike several years ago. They were orthoses with thigh and leg lacers, and quite often with an ischial seat and foot plates with a molded sandal. At the knee joint a swiss lock was as good as standard. The lower bars had a simple stirrup, and stops at the ankle joint, but the almost free motion defeated the functional purpose. Pelvic belts with hip joint, in most cases with a restricting lock, were added for the more severely paralyzed with involvement of the hip muscles. This resulted in a complete enclosure of the extremity, muscular damage, and the restriction of important joints. No doubt, this method accomplished a maximum of mechanical fixation which could not be exceeded by any other technique.

Professor Schede once wrote much about, "mechanically aided paralyzed," and I quote: "One is able to stand up any patient, if he is in fixation from the top to the bottom but all he would become is a statue leaning against something, unable to move."

The past years have seen a considerable change of opinion on the side of the physician as well as the orthotist. The principle of total fixation or stabilization of the joints does not determine the design of the orthosis, but the purposeful synergy of stability and functional freedom of motion of the patient. This development has been influenced by the deciding progress of the strictly doctoral therapy. The immediate and careful treatment by the physician for cases of poliomyelitis is preventing lasting damage to the kinetic system as well as to the joints. Purposeful positioning of the extremities has made contractures of the joints a rarity today. The diseased muscles are being placed at ease and the hyper-extension avoided. The blood circulation of the damaged muscles is stimulated through thermotherapy and light massages. The muscles are re-trained through early applied controlled physical therapy. Therapeutic procedures supported by load resisting exercises and active exercises in warm water whirlpools are extraordinarily successful. At times lengthy, tiresome and intensive treatments of the polio patient should not be under-estimated in their effectiveness. They are of tremendous psychological value since they represent the first

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steps for the patient to ambulate with or without assistance, on his way towards the regaining of his physical independence.

Today we know that a fairly correct evaluation of the overall damage to the muscular system can not be made until after approximately two years. Damage to the neuro-muscular unity resulting in the loss of the ability to ambulate leaves the physician the choice between two therapeutical procedures: (a) Surgery, or (b) application of an orthosis. If the occasion arises, surgery as a pre-requisite for the successful application of an orthosis.

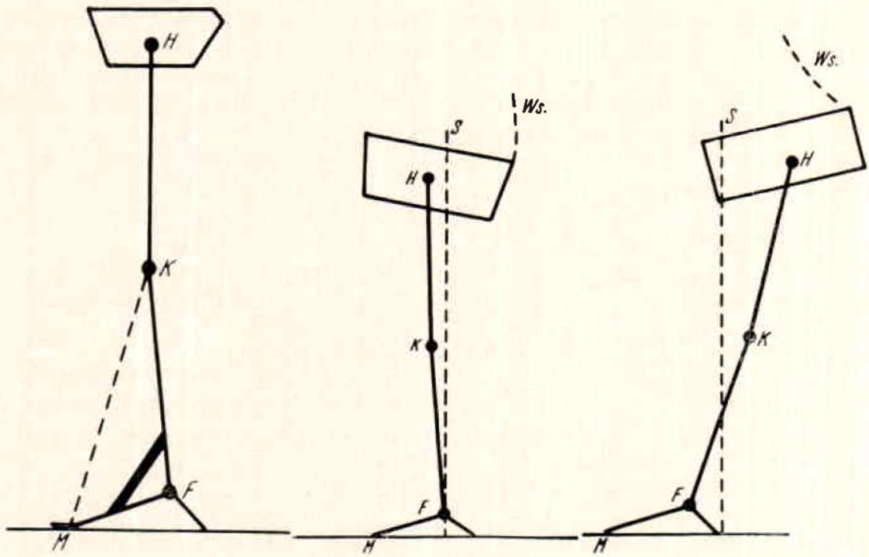
The surgical procedures include the osteotomy for the elimination of contractures and malalignment, tendon transfer as well as muscle plastics and the immobilization of joints. The arthrodesis fixation of the paralyzed extremities should be mentioned as a more or less final surgical procedure which requires a rather strict indication. Surgery of this type is creating a irreversible situation, and thorough evaluations of the individual case are a necessity. The indication for an orthosis will be given if surgical techniques are unable to assure a definite improvement of mobility, or if damages through mal weight bearing are to be expected. The physician and the orthotist will have to discuss the design of the orthosis before a prescription can be made. However, the prescribing physician should be able to expect that the orthotist has full knowledge of each and every technical aspect.

Orthoses can be of many different designs, but only one will meet the requirements of the individual case. It is difficult to determine the technical features of an orthosis in advance, since the patient instinctively will try to compensate for the liability of his paralyzed extremities. He will still activate existing muscles, swinging his shoulders and other compensatory body movements. Such proceedings demonstrate how disadvantaged pelvic components often can be. They simply limit compensatory freedom of motion and become in spite of their erective and supportive action limiting and bothersome. An exemption would be the considerable loss of muscles of the pelvic area. But even here, should we only use pelvic components if the hip muscles are bilaterally weak or completely paralyzed. The paralytic scoliosis is an additional indication which necessitates complex bracing with the use of pelvic and spinal attachments.

Clinics started to use temporary splints like plaster shells which are easy and fast to fabricate, after it was realized that an evaluation and period of training was necessary. These temporary splints are most useful in determining the mechanical support needed for satisfactory ambulation. This method is also of therapeutic value for the patient. Physician and orthotist are often surprised with how little assistance a patient is able to ambulate. Quite often we will be able to observe a gait that appears impossible to the observer familiar with the normal phase of locomotion. Often we would be disappointed to think that we could improve such a gait through mechanical assistance. We would only restrict the patient in his movements and he would lose control over his motions. It is difficult, and at times, impossible to analyze such proceedings.

An orthosis can only be properly designed if the orthotist has full knowledge of the various methods used to accomplish one or the other effect.

We should mention the mechanical stop controlling the dorsal flexion of the foot in connection with this. The full value of the dorsal stop for the stabilization of the lower extremity joints has even today not been fully realized. The dorsal stop at the ankle joint will find application if the gastrocnemius is paralyzed. The action of the dorsal stop in relation to the knee joint is also of great importance since we stabilize the knee joint during walking phases from mid-stance to heel off.



Illustrations 1, 2 and 3

ILLUSTRATION #1

This means that it is possible to influence the stability of the knee joint positively from the ankle joint. However, hyper-extension of the knee has been created. This necessitates the incorporation of the thigh in the orthosis in many cases.

ILLUSTRATION #2

The mechanical knee joint will have to be aligned in such a manner that it permits just as much recurvatum as it takes to stabilize the knee. The influence on the hip joint and pelvis should not be overlooked. Increase of the equinus position (increase of the dorsal stop) will react positively on the stability of the knee. The pelvis will be tilted anteriorly (the hip joint flexed) especially if the gluteus maximus and medius are paralyzed. The dorsal stop will have to be so adjusted (taking the height of the heel into consideration) that the stability of the knee is assured and the pelvis erected. A "gluteus strap" is of assistance if the need arises. The pelvis will find its erection and point of stabilization through the leverage of the fore foot.

ILLUSTRATION #3

However, it would be wrong to believe that the dorsal stop has to be used for every orthosis aiding a paralyzed lower extremity. The individual case should always be the determining factor. A present arthrodesis will eliminate a dorsal stop very often. Such a surgical procedure will simplify the design of a orthosis. In many instances the stability of the knee can only be achieved through a mechanical knee lock. This is definitely true about the paraplegic patient. Even though we should try to find a design avoiding a knee lock whenever possible, a freely moving knee is of psychological advantage to the patient. Furthermore existing muscles will be exercised with every step and the appearance of the gait is more natural. It will take special effort and repeated experimenting to reach this goal. A financier has very little understanding of the time of testing involved to find the best mechanical solution for the patient. He will only see the completed product and not the effort it took to accomplish the final features. It is possible though to establish basic principles in spite of the difficulties involved in pre-determining the final design of an orthosis. Paralysis of the lower leg for instance.

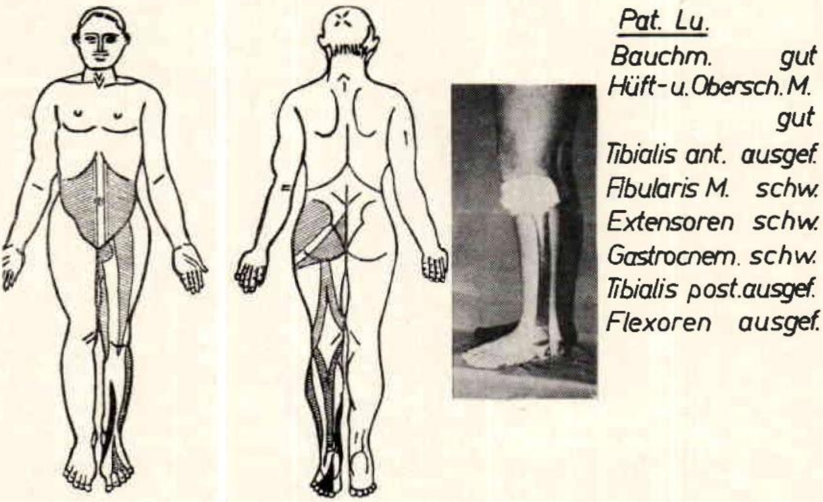


ILLUSTRATION #4

Patient Lu.	
Abdominal muscles	functional
Hip & thigh muscles	functional
Tibial anterior	paralyzed
Fibularis muscle	weak
Extensors	weak
Gastrocnemius	weak
Tibialis posterior	paralyzed
Flexors	paralyzed

ILLUSTRATION #4

The gastrocnemius, flexors and tibialis anterior and posterior would result in a typical valgus deformity. We would observe a weakness of the powerful plantar flexion and the stability of the knee besides the malposition of the foot. The appearance of the gait becomes awkward. The foot will slap to the floor without any resistance at heel contact. The lifting of the heel from the floor is also impossible. This picture of a deformity would question the need for an orthosis. This question, in general can not be answered with a Yes or No.

The patient no doubt is able to ambulate, and it happens only too often that the patient ingeniously compensates for the lost motions during the phases of gait. It depends on the individual case to justify an orthosis. An orthosis is indicated where it is necessary to enable the patient to do extensive walking and to improve the appearance of his gait. The knee stability of the patient will also benefit from an orthosis.

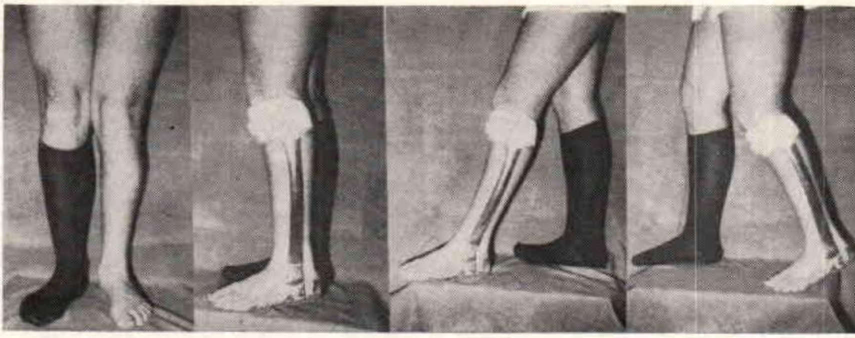
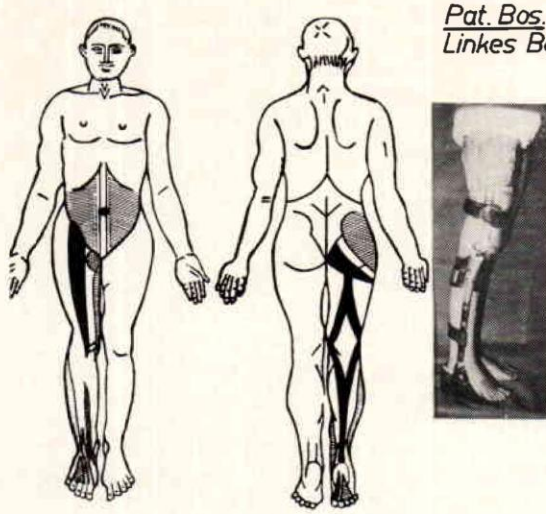


ILLUSTRATION #5

Another example will demonstrate how it is possible to stabilize the joints with little mechanical effort.



Pat. Bos. Bauchm. gut
Linkes Bein ohne Ausfälle
Rechtes Bein:
Iliopsoas schw.
Adduktoren schw.
Glut. med. u. min. schw.
Glut. max. ausgef.
Quadriceps ausgef.
Biceps u. Semi. ausgef.
Tibialis ant. ausgef.
Fibularis M. gut
Ext. hall. long. gut
Ext. dig. long. u. brev. schw.
Gastrocnemius ausgef.
Tibialis post. schw.
Flexor hall. long. ausgef.
Flexoren dig. schw.

ILLUSTRATION #6

Patient Bos.

Abdominal muscles	functional
Left leg	no loss of muscles
Right leg	
Iliopsoas	weak
Adductors	weak
Gluteus medius & minimus	paralyzed
Quadriceps femoris	paralyzed
Biceps, semitendonosis & membranosis	paralyzed
Tibialis anterior	paralyzed
Fibularis	functional
Extensor hallucis longis	functional
Extensor digitorum longus & brevis	weak
Gastrocnemius	paralyzed
Tibialis posterior	weak
Flexor hallucis longus	paralyzed
Flexor digitorium	weak

Demonstrates the relatively extensive loss of muscles of this patient. In this case, the gluteus medius and minimus are partially paralyzed. The gluteus maximus as well as the quadriceps, biceps, semitendonosus, semimembranosus, gastrocnemius, flexor hallucis longus and the tibialis anterior are completely paralyzed. The iliopsoas, adductors, tibialis posterior and the digital flexors are weak. The function of the abdominal muscles, fibularis muscles and the hallucis longus are functioning normally. We are confronted with a situation which would make an ambulation without fixation of the hip and knee joint usually questionable. But in this case, was it possible to utilize an orthosis which had neither locks at the knee joint nor at the hip joint. Sufficient stability was provided even though it was not at first expected.

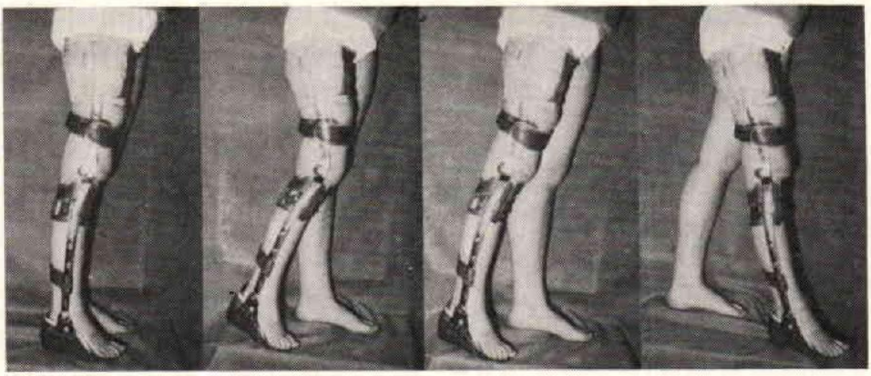


ILLUSTRATION #7

The mechanical dorsal stop was of greatest importance in the case of this orthotic problem. The stabilized foot has the function of a knee lever action, as previously indicated. The extremely posterior located mechanical knee joint became through this lever action markedly more effective. But not only the influence on the knee joint was of advantage, the hip joint gained the ability of full extension based on the foundation of the fore foot. The weak gluteus minimus and medius aided little, but still were some support. It should not be overlooked that the hip muscles of the unaffected side are fully functional and represent a partial compensation for the affected side. It is recommendable in such a case to use an orthosis with a short thigh lacer. Such a lacer helps to establish an intimate contact between orthosis and extremity, especially in the region of the hip joint. Ischial weight bearing is impractical, since it would interfere with the extension of the pelvis in this particular case. Only a well designed orthosis with a dorsal stop can feature the stability of joints without application of locks. Some support for the function of this orthosis was found in the flexor digitorum longus and brevis supplementing the knee joint. The rather weak adductors, gluteus medius and minimus supported the hip joint. It should be a most desirable task for the orthotist to design an orthosis which stimulates the function of such weak muscular forces and still permits a secure but much more natural gait. The next case is a polio patient with partial paralysis of both lower extremities.

ILLUSTRATION #8

The status of the muscular system is: (a) Functional abdominal muscles, as well as on the right side the gluteus maximus, medius and minimus, biceps, semitendonosus, semimembranosus, gastrocnemius, tibialis posterior, fibularis longus and the flexors. On the left side: the gluteus maximus,

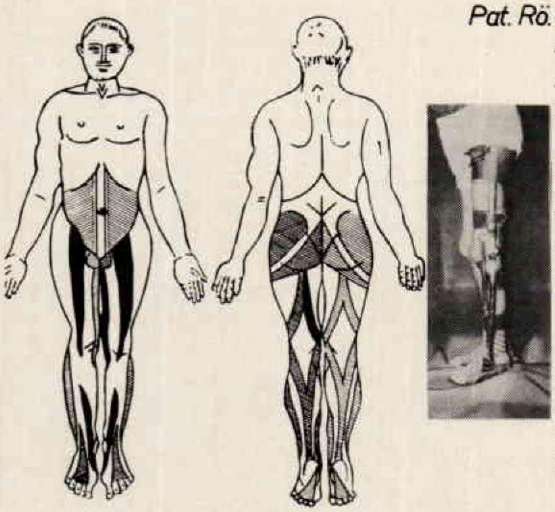


ILLUSTRATION #8

Patient Ro.

Abdominal muscles		functional
Iliopsoas	Right	functional
	Left	weak
Adductors	Right	functional
	Left	paralyzed
Gluteus maximus, medius & minimus	Right	functional
	Left	weak
Quadriceps femuris	Right	paralyzed
	Left	paralyzed
Biceps	Right	functional
	Left	weak
Semimembranosis & tendonosis	Right	functional
	Left	paralyzed
Tibialis anterior	Right	paralyzed
	Left	paralyzed
Tibialis posterior	Right	functional
	Left	weak
Fibularis longus	Right	functional
	Left	weak
Extensors	Right	weak
	Left	weak
Flexors	Right	functional
	Left	functional

medius and minimus are weak, and the important quadriceps is not functional. The quadriceps of the right side is also paralyzed. The iliopsoas of the right side is functional but weak on the left side. The adductors of the right side are not involved, but on the left side along with the semimembranosis and semitendonosis are not functioninng. The biceps, gastrocnemius and fibularis longus of the left side are also weak. The tibialis anterior on both sides are paralyzed and the extensors show only little function. Primary bracing was applied to the left side only in spite of the severeness of the paralysis. The orthosis featured a free ankle joint and a lock at the knee joint.

This young man had suffered continuously from his handicap and his awkward gait caused him to feel depressed. He was fitted with a new orthosis six months ago. We had the intention of accomplishing free motion at the knee joint. The weak muscles of the calf and the functional extensors made it necessary to move the ankle joint extremely anterior. The locating of the ankle joint along with the dorsal stop was most important in creating the most beneficial alignment for the mechanical knee and hip joint.

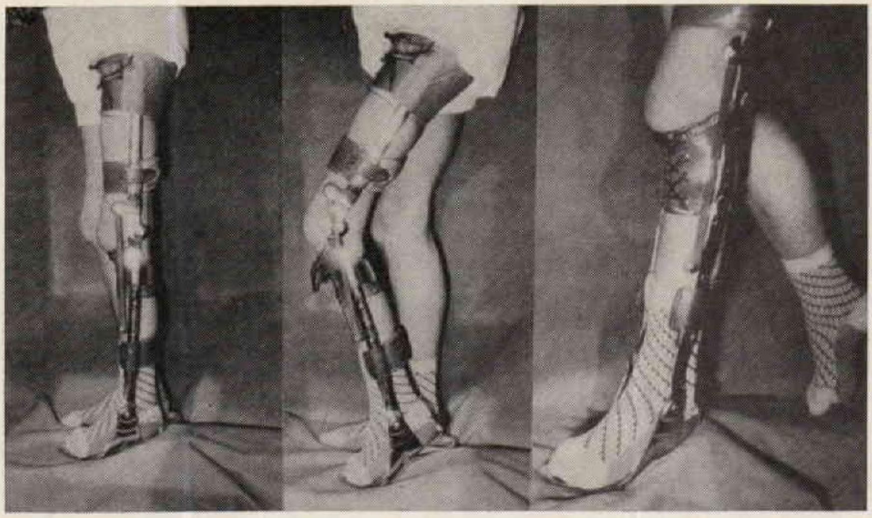
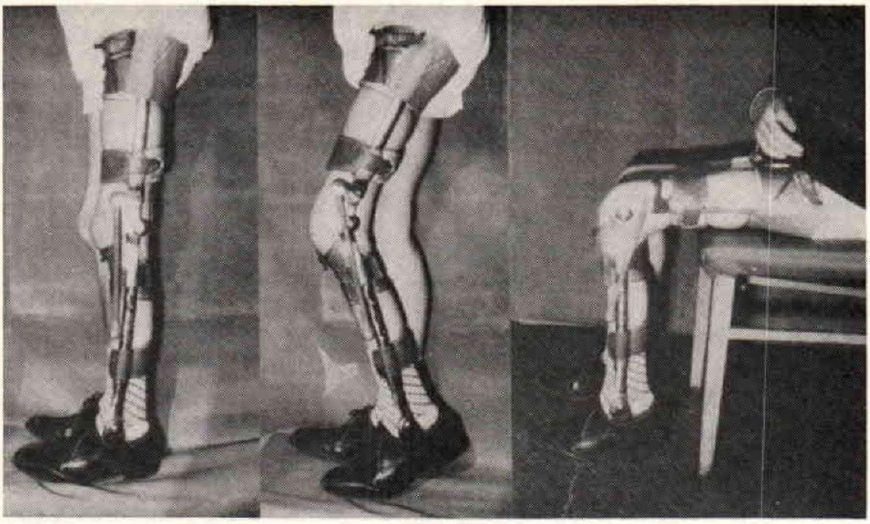


ILLUSTRATION #9

This picture demonstrates the extremely posterior location of the mechanical knee joint. A short thigh lacer was incorporated to assure good contact between orthosis and extremity. Sufficient knee stability was not achieved immediately, even though the stops of the ankle and knee joint were carefully aligned. The missing knee extensors of the right side represented one cause for instability which was noticed on inclines and uneven ground. The inability to use the extensors of the left side for compensatory movements was another reason. Full knee stability was accomplished after application of a knee extension assist. The extension assist consists of an especially fabricated strong elastic tendon with reinforcements of fabric at the points of attachment. The points of attachment of this assist in relation to the knee joint can be moved anterior or posterior. A correctly located assist will assure assistance in extension up to a flexion angle of 140 degrees, the average flexion of the knee during the gait phase. Another benefit of the assist is the fact that the extension assistance changes to flexion assistance once the knee has been flexed beyond 140 degrees. The extension assist moves posterior to the knee center during knee flexion.

ILLUSTRATION #10

There is a marked difference between the laterally attached assist and knee caps or other knee extending elastic straps which exert pressure on the knee joint during flexion. Only patient and extensive testing made it possible to establish a relatively good gait and a considerable freedom of motion. I would like to mention that the strong flexors as well as the weak gastrocnemius somewhat assisted in stabilizing the joints. It was also important to permit full plantar flexion to prevent a pushing force during knee flexion. The mechanical stops of the ankle joint must also be accurately adjusted for the height of the heel. It was most satisfying to witness the joyfulness



of this young man about the freely moving knee joint which permitted him to ambulate almost normally with only little restriction.

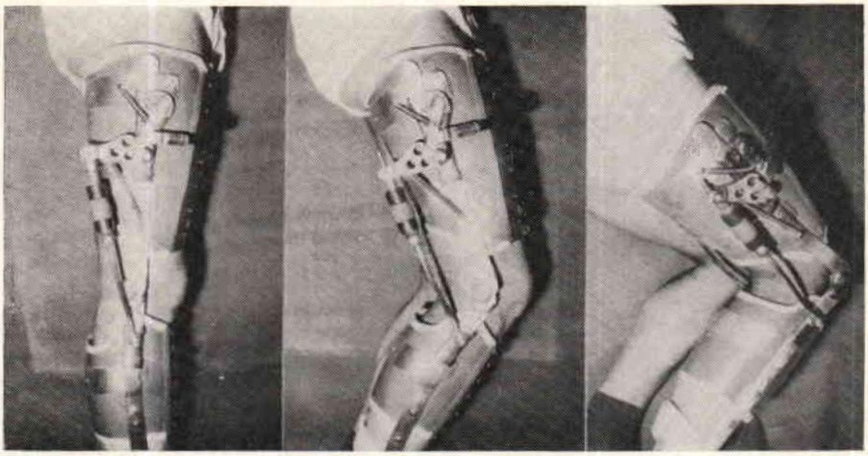
Taking such experiences into consideration, the orthotist should always make a thorough study of the muscular conditions of his patient before he carefully plans the design of the orthosis. His aim should be the utilization of even the weakest muscular functions, and the least restriction of motion from the orthosis. These considerations are of the greatest importance to the patient. However, I have to mention that we reach our goals only after a period of training and getting familiar with the new and different orthoses. A positive approach on behalf of the patient is a necessity for success.

I am going to demonstrate an experimental orthosis as the last example of my representation about individual technical aid for the paralyzed lower extremity. This orthosis was designed for a very specific cause.

The patient had experienced a considerable recovery from severe poliomyelitis. An orthosis was not an absolute necessity any more. However, on occasion it would happen that uneven ground, doorsteps, and carpet borders would cause instability of his knees. Compensatory movements were not sufficient to prevent falling. The result was a history of torn and pulled ligaments, hemorrhages and severe damage to the knee joints, etc.

An experimental orthosis was designed featuring free motion of the knee during the walking cycle. However, the motion at the knee would come to a stop if the patient should stumble. This locking of the knee joint could not become active spontaneously, but had to become effective with some elasticity. The forces occurring at the knee are excessive and the solution achieved is definitely not suitable for general application. Nevertheless, I believe it to be of value to continue to work with this particular problem. We know of many cases which in case they stumble, need a soft applying brake to prevent a fall. There is definitely a very close parallel to the prosthetic knee.

The present case found a full mechanical solution of the problem. The cosmesis of the design was not acceptable nor recommendable. The me-



chanical principle of the connecting rod as was used for this particular case. The involuntary flexion of the patient's knee was brought to an "elastic stop" at a flexion angle of 145 degrees and injury of the knee prevented. A lever could be triggered to accomplish full knee flexion.

As I have mentioned previously, the forces at the time of the braking of the knee are excessive. Pneumatic or hydraulic brake units should be most useful for such a case, providing they had a cosmetically acceptable design and location. I have mentioned this problem because of the demand for this type of technical assistance which so far has not found a satisfying solution. It is the soft, elastic braking when standing up under heaviest pressures that would be most desirable. The illustrations demonstrate only a modest beginning in a state of testing.

The above captioned statements are meant to demonstrate the many possibilities for orthotic devices in case of paralysis of the lower extremity. My primary interest concentrated on designs which feature a maximum of stability, and still permit the highest degree of motion without mechanical interference.

I see in this the essentials of modern technical orthotics. There is also the demand for an intensive study of each case in its individuality when it is presented to us. It will only be through such efforts that it will become possible to aid the patient with the best possible orthotic appliance.