Above-Knee Prosthetic Techniques In Germany*

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The technique of artificial limb fitting has received great impetus in the last fifty years as a consequence of two wars. The endeavors made before this, of course, especially by mechanics who were interested in the subject, and frequently by amputated persons themselves, had led to very serviceable prostheses about which we find valuable references in medical literature.

However, the great number of wounded persons from the two World Wars presented both doctors and technicians with the task of considering prostheses both from the physiological and from the technical side, and of solving the new problems which constantly appeared as progress advanced.

In Germany it was Prof. Schede who had decisive influence on the development of the A/K prosthesis. He was the first to work out the exact physical-scientific principles which are set forth in his book "Theoretische Grundlagen im Kunstbeinbau" [Basic Theories in the Construction of Artificial Legs.] After Prof. Schede, Prof. Zur Verth and Dr. Gorlach also did a great deal for the further development of prosthetic techniques in Germany.

As a result of this medical research and of their own discoveries, many important persons have contributed interesting constructions which have been of the greatest benefit to the prosthetic technique. In this field doctors and technicians have worked together in the closest cooperation and their mutual comprehension has led to the finest results.

In this report I will deal chiefly with the question of German prostheses for thigh amputations since this wish was expressed by the head of your society.

It was good fortune that my father was associated with Prof. Schede in 1916, and that, in an army hospital in Munich, they made the first attempts at a newer development of the prostheses known in those days.

Very soon the following points were recognized as the most important in constructing prostheses:

1. Careful, individual fitting of the stump in the prothesis,
2. Support of the body weight on the ischial tuberosity,
3. Static-dynamic alignment of the prosthesis, and
4. Greatest possible stability through knee- and foot-joint constructions.

In this order I will report on the methods used by us in Germany in making thigh prostheses and trust that this will answer a number of questions which interest the American prosthetist.

The fitting of the stump in the socket can only be accomplished when considered together with the supporting of the body weight on the ischial

* From a lecture by Mr. Habermann, given before the 1960 National Assembly of the American Orthotics and Prosthetics Association in New York City.

tuberosity since these two complexes are closely related. I even consider it necessary to discuss the latter point first, since the socket for ischial bearing has great influence on the general construction of the upper portion of the prosthesis.

All of my statements are based on the supposition that the stump is in a condition to be fitted with a prosthesis: That is, that physiological movements are not restricted by contractions, and also that the scar-area is not painful and the soft tissues over the distal end of the femur have not grown together with it. Stumps which still show contractions are more difficult to fit with a prosthesis, and performance with the prosthesis is reduced. For purposes of clarity I will briefly explain the static and functional situation at an amputation of the thigh.

The hip-joint on the non-affected side bears the weight during the phases of standing and walking, and at the same time it is a point of rotation for all flexing and extension movements, and for abduction, adduction, and

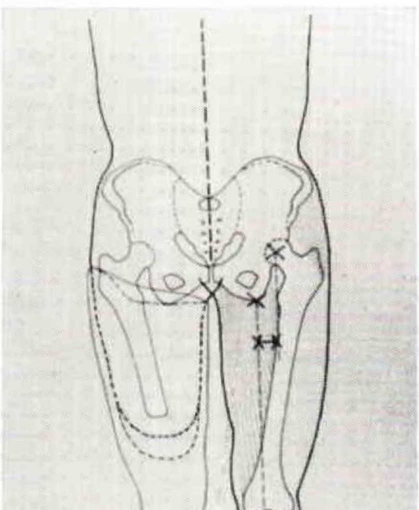

Figure 1. The prosthetic side is here in the swing-phase. On the normal side the abductors keep the pelvis in the horizontal plane. They act around the hip-joint, which, at the same time, is also the point of support.

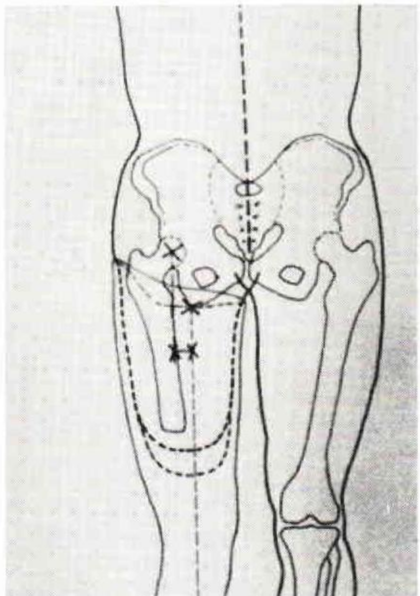

Figure 2. The sound side is now in the swing-phase. On the amputation side the abductors must keep the pelvis in the horizontal plane. The hip-joint is only the point of rotation, it is not the point of support any longer. The tuber ossis ischii is the loading point. But it lies medially from the hip-joint.

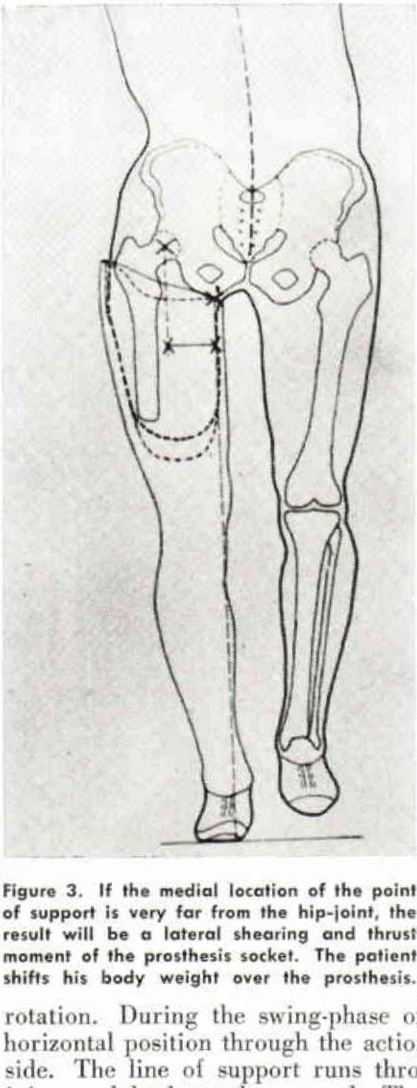

Figure 3. If the medial location of the point of support is very far from the hip-joint, the result will be a lateral shearing and thrust moment of the prosthesis socket. The patient shifts his body weight over the prosthesis.

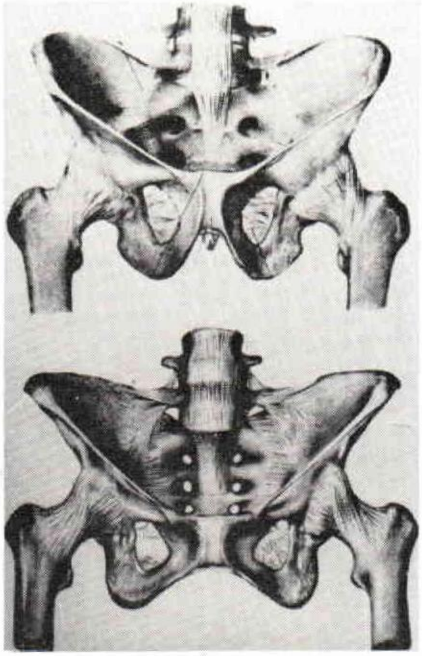

Figure 4. Above male pelvis, below female pelvis. It is clearly shown that in the case of the female pelvis the tuber ossis ischii comes essentially closer to the hip-joint with its lateral portion.

rotation. During the swing-phase of the prosthesis the pelvis is kept in a horizontal position through the action of the abductor muscles on the sound side. The line of support runs through the middle of the hip-joint, knee-joint, and heel, to the ground. The abductor muscles on the non-affected side act directly on the rotation point, the hip, and the line of support.

During the phase when the weight is borne by the amputated side, that is to say, during the swing-phase of the sound leg, the hip-joint is also a rotation point for the stump, but it no longer carries the full weight of the body. The ischial tuberosity, which bears a considerable part of the weight of the body and is also a point of rotation for the prosthesis, is now located, from a frontal view, below and medial to the hip-joint, while, from the sagittal view, the tuberosity lies behind the hip-joint. The discrepancy between the hip-joint and the ischial tuberosity reduces the power of the abductor muscles to maintain the pelvis in a horizontal position during the swing-phase of the sound leg. This means that through the space between the physiological point of rotation (the hip-joint), around which the abductor muscles act, the mechanical point of rotation and weight-bearing (the ischial tuberosity) there is a shearing force and thrust against the rim of the superior portion of the prosthesis when abduction occurs. This again means that the abductor muscles are unable to maintain the pelvis in a horizontal position, and in order to re-establish balance there are changes of posture. The aim in fitting the bucket is to bring the prosthesis into line with the pelvis so that the shearing force and thrust, which have both a functional and mechanical origin, are reduced to a minimum. If it is possible, through body weight on the lateral part of the ischial tuberosity, to bring the weight-bearing point of the prosthesis and the rotation-point of the stump closer together, the function of the abductor muscles is improved and the shearing force is reduced. The abductor muscles are then in the position to keep the pelvis horizontal during the swing-phase of the non-affected leg.

If the point of body weight is medial, especially in the area of the pubic bone, the performance of the abductor muscles is considerably reduced and there is a side-thrust by means of which the prosthesis is displaced in a lateral direction and the weight-bearing point of the pelvis is displaced medially. Pressure in the area of the perineum and at the lateral end of the stump are the consequences of this situation.

Very often we find that women who have been amputated have a much better gait and attract much less attention with their prostheses than men. In general this is considered to be a matter of vanity, and it is held that men do not always attach much value to the way they walk. The actual reason, however, is far more probably the difference in the pelvis. In the case of women the position of the ischial tuberosity permits the body weight to be carried proximal to the hip-joint, which makes for considerably better static and functional conditions, whereas in the case of the male pelvis there is a much greater distance between the ischial tuberosity and the hip-joint.

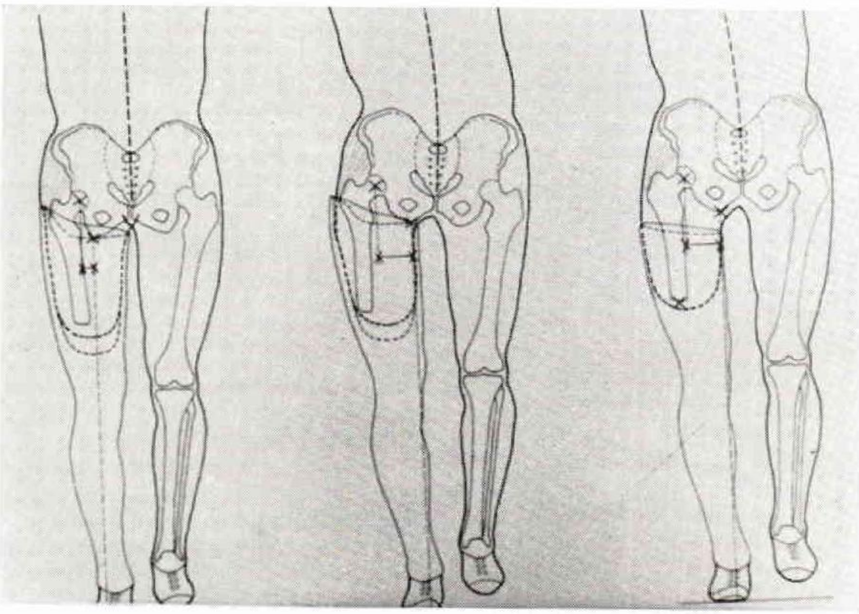

Figure 5. This survey again shows the effects with various initial positions. It is functionally bad in the case of medial support, the same applies to the stump end load without tuber seat.

The facts I have stated show also that when less body weight is supported by the ischial tuberosity, and more by the soft tissues, the non-physiological situation is aggravated, and in the worst case weight on the stump end without any weight being borne by the ischial tuberosity would be particularly harmful.

I must stress the fact, however, that this has nothing to do with the efforts made nowadays to establish contact of the end of the stump with the bottom of the bucket, for this development is based on quite different considerations which have nothing to do with the static conditions I have mentioned. I myself am convinced that the contact of the stump end with the bottom of the bucket if it is properly modelled can have a very favorable influence on the circulation, in particular, of the stump-end. The attempts I have made myself in this direction have shown very positive results up to now.

Naturally, the body-weight is not borne only by the ischial tuberosity, for, by the moderate compression of the stump in the bucket, the surfaces of the stump carry weight too. But this must not be allowed to disturb functional activity in the hip area. All these processes in the pelvic and hip area of the amputated side are, in our opinion, of decisive importance and we must do everything possible to see that when the socket is fitted to the stump the muscles which move the hip-joint are not restricted in their physiological action. I will remind you in this connection of the typical walk of a person with a dislocated hip, where incompetency of the abductor hip muscles leads to "waddling," the upper part of the body being shifted each time to whichever side bears the weight. The results in this case are comparable with those in a thigh prosthesis when the ischial tuberosity lies medially and thus rests on the socket. In this connection I should like to draw your attention to the highly interesting studies by Prof. Radcliffe who also dealt with this subject in detail. I think I may assume that our views about the problem do not differ very much.

But other features are important too in fitting the socket to the stump. Hip extension on the amputated side, effected by the Musculus glutaeus maximus, can be impeded by the way in which the ischial tuberosity rests upon the socket, since, at extension, the ischial tuberosity lies behind the rotation-point, the hip-joint. Therefore, the socket for ischial bearing must be shaped in such a way that the ischial tuberosity can roll on the surface of the socket in the phase of hip-extension. The front rim of the bucket, which is about 1 inch higher than the ischial bearing socket, offers a

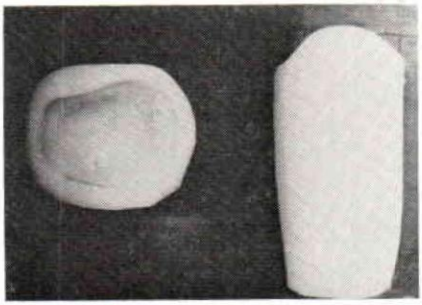

Figure 6. Socket shape as it is produced by our method.

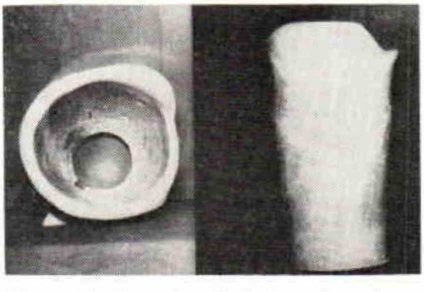

Figure 7. Example of bad socket shape; there are complaints in the perineum, as the tuber ossis ischii has no fixing point on the socket, resulting into a lateral shearing moment. The deep cutting at the socket can be clearly seen, but this does not bring about any improvement of the situation.

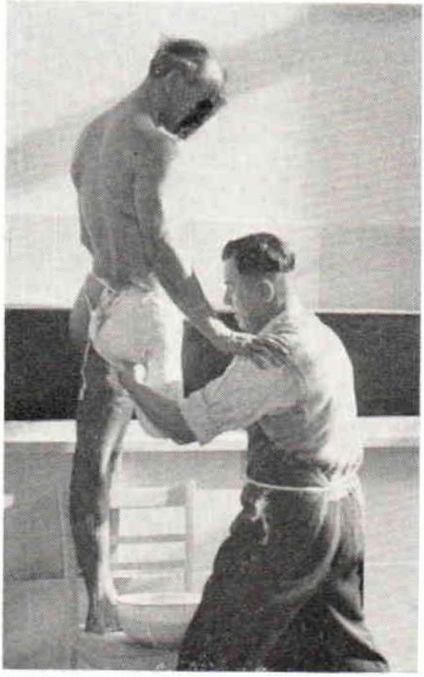

Figure 8. Plaster cast of stump.

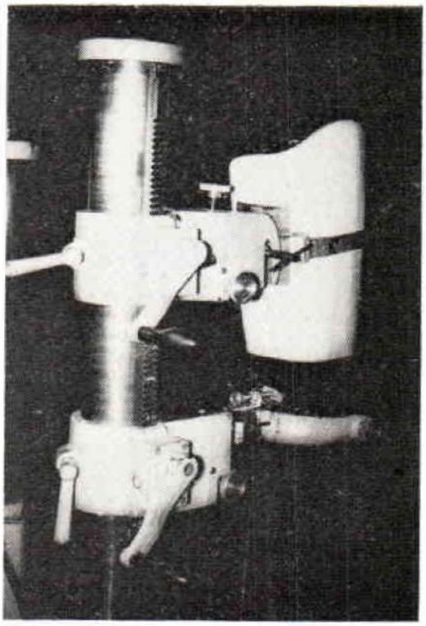

Figure 10. The upper socket is clamped in the setting-up appliance.

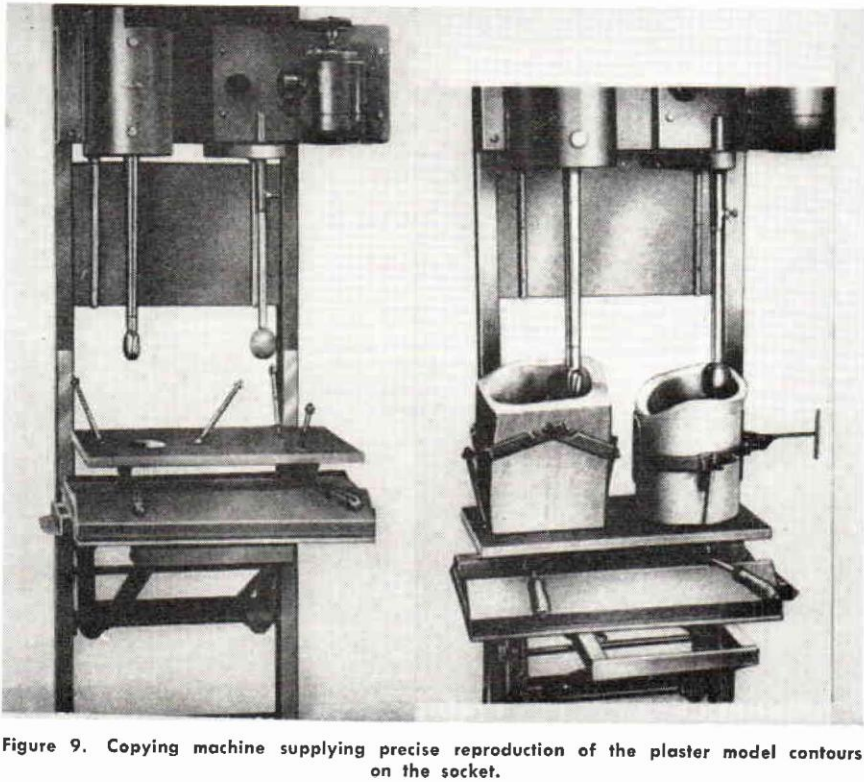

Figure 9. Copying machine supplying precise reproduction of the plaster model contours on the socket.

counter-support in this case. The contraction of the Musculus glutaeus maximus at hip-extension is provided for by leaving a certain play for the muscular tension at the side of the ischial bearing socket, since otherwise this powerful muscle would push the prosthesis in a lateral direction. All other muscles in the area of the superior portion of the prosthesis must be given so much play when the socket is fitted that, at contraction, there is no change in the position of the prosthesis.

The contours of the bucket which fit these requirements can be established, according to our experience, only by a plaster cast of the stump. For a better demonstration, therefore, I should like to show you our method with a plaster model. (In a speech delivered on September 5, 1960 at the meeting of A.O.P.A. at the Waldorf-Astoria Hotel the lecturer demonstrated in detail the application of a stump plaster cast.)

In this way we obtain a complete impression of the stump in which all the contours are reproduced and at the same time the anatomical position of the ischial tuberosity is fixed. This plaster cast is now the pattern for the upper part of the prosthesis. It is reinforced with plaster around the outside and cast in a receptacle so that it can be fixed on the copying machine. The machine shapes with mechanical precision the form of the plaster model in the upper part of the prosthesis. The copying machine saves the orthopedic technician the work of routing by hand. By the use of feelers of various sizes the transfer from the model to the prosthesis can be varied in size. This makes it possible, by using a larger feeler, to keep the diameter of the socket a little smaller, as is the usual practice.

After this comes the fitting of the copied thigh piece in the static apparatus. The position can now be adapted at a higher or lower level, in abduction or adduction, flexion or extension. When the thigh piece has been fitted into the static apparatus the stump is inserted into it with the help of a sock. Now the actual adjustment takes place, as I have already described. Not until the ischial tuberosity is supported properly from the lateral aspect and we are satisfied with the fit of the thigh piece in general is the final position fixed, it being necessary to make sure that the abductor muscles in particular, but also the other hip muscles too, are able to function physiologically both when the amputated person walks and stands. Figures 10 through 17 demonstrate the fitting.

The section planes thus obtained are the prerequisite for every further construction. Many variations are possible, it being necessary only to shift two parts and bring them together, without changing the position of the shaft in the apparatus. Any protuberance of the knee assembly can be corrected cosmetically and adjusted; a twist of the horizontal section plane suffices, and the position of the shaft itself remains unchanged.

The thigh piece is placed upon the knee assembly in such a way that the ischial tuberosity lies vertically above the middle of the knee-joint and the lateral margin of the heel. The separate parts of the prosthesis are now screwed together and prepared for the first steps. One can now see whether the thigh piece is properly adjusted to the contours of the stump and allows for the proper functioning of the muscles, for every cramping of muscle contraction shifts or twists the shaft and makes the position of the ischial tuberosity on the prosthesis unsteady.

At the moment we are engaged in experiments to fit the upper portion of the thigh piece without the shaft, and also to determine the position of the shaft independent of this uppermost portion of the thigh piece. These experiments are based on the consideration that the ischial tuberosity is a

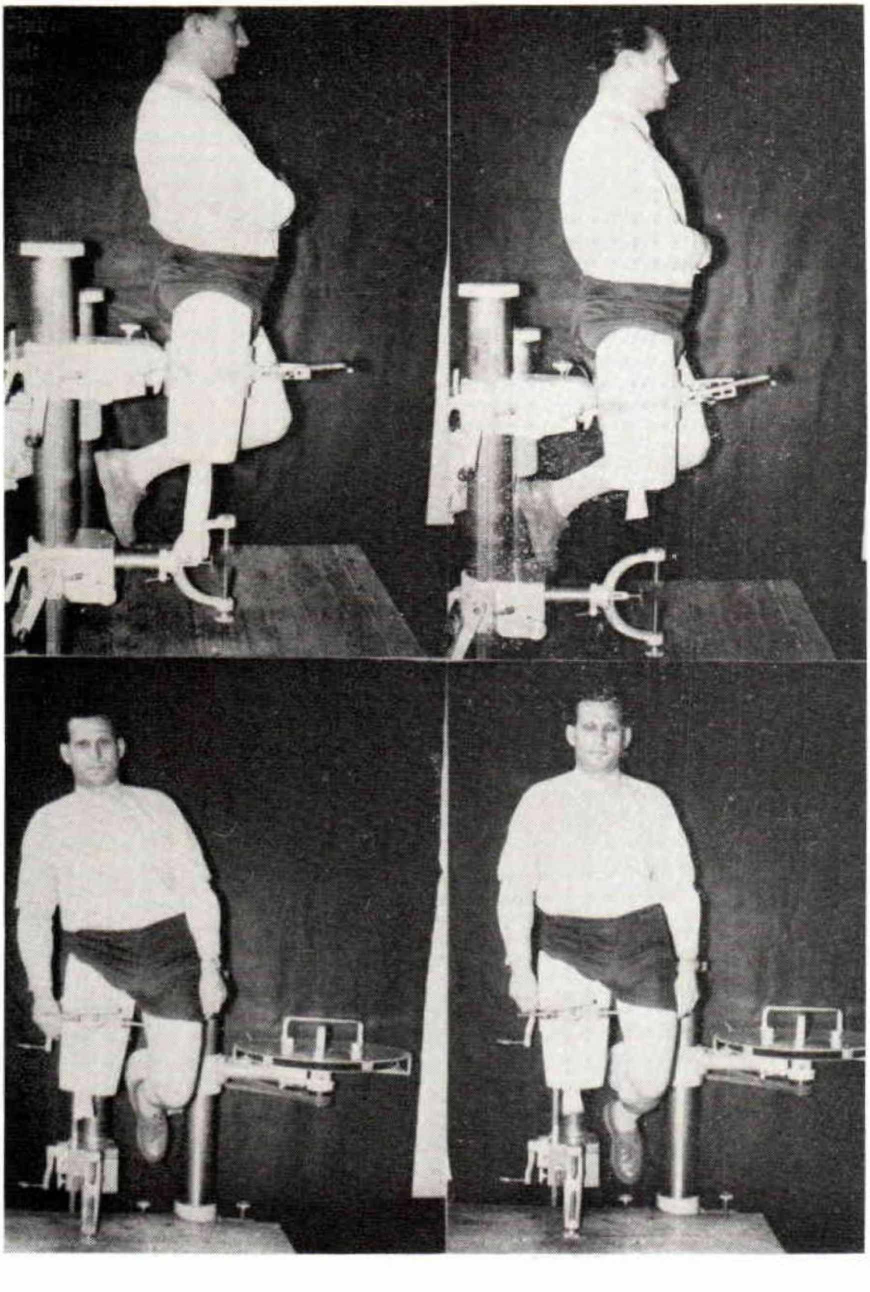

Figure 11. Excessive extension position of the socket must be compensated by the patient with increased lumbar lordosis. In the case of increased abduction position of the socket the patient must shift his body weight to the prosthesis side for the maintenance of balance. In normal posiion the hip musculature may keep the pelvis and the upper part of the body under favorable conditions.

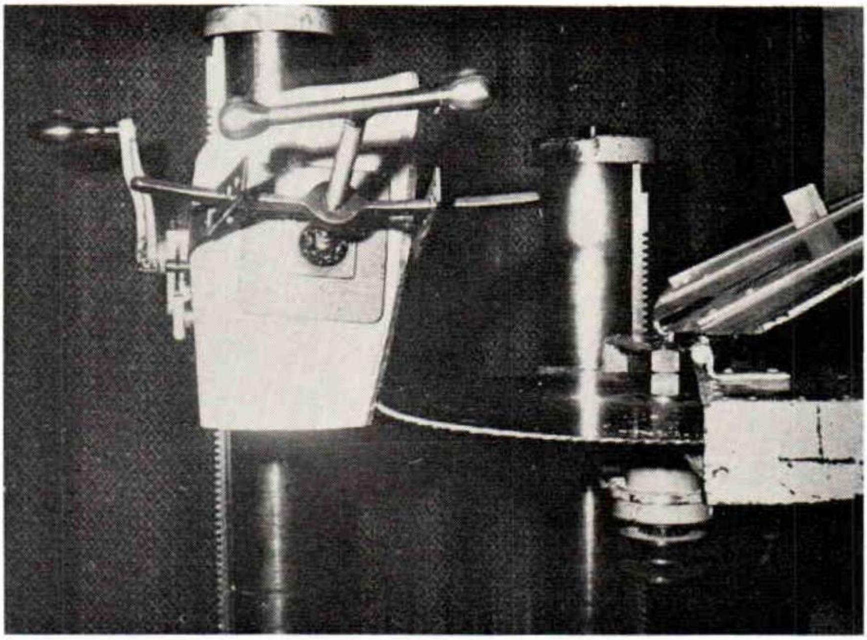

Figure 12. The upper socket is horizontally cut off at the bottom in the position ascertained.

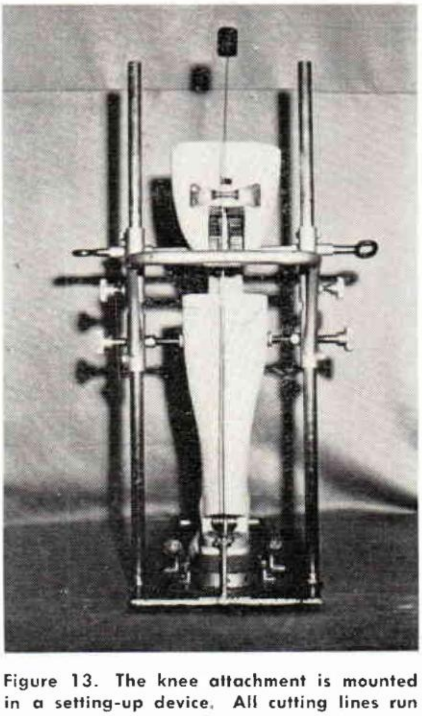

Figure 13. The knee attachment is mounted in a setting-up device. All cutting lines run horizontally.

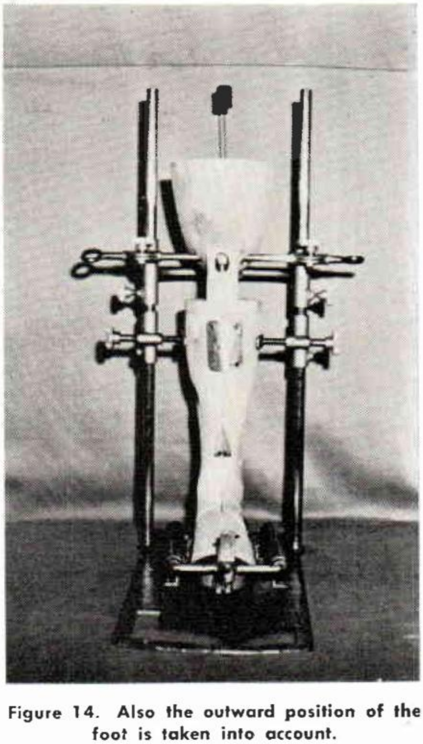

Figure 14. Also the outward position of the foot is taken into account.

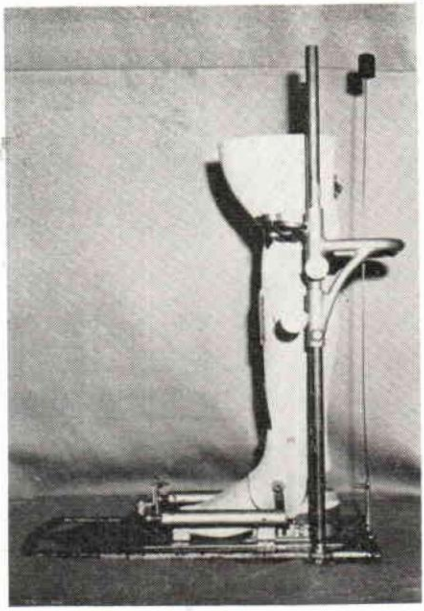

Figure 15. Side view of the appliance. The position of the knee-joint to the axis of the ankle is determined.

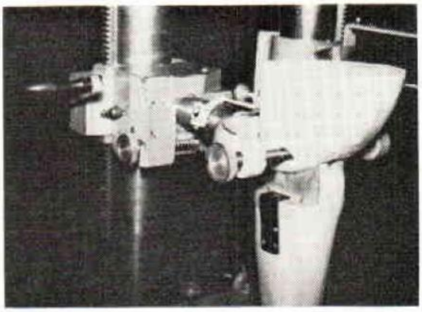

Figure 16. The mounted knee attachment is now clamped in the great setting-up appliance between 2 dead centers. . . .

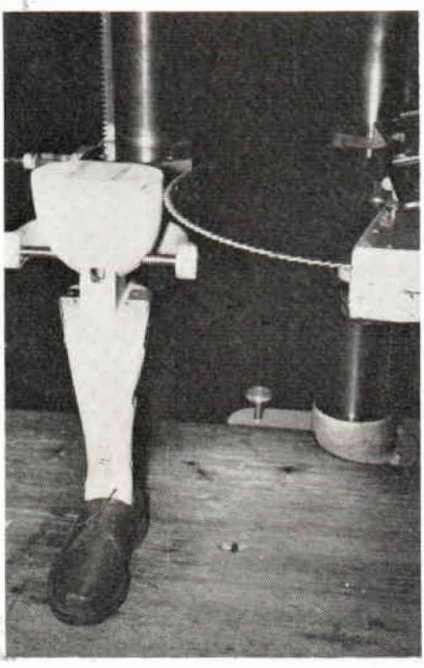

Figure 17. and horizontally cut off by the circular saw adjusted correspondingly.

Figure 18. The patient can load the prosthesis in the flexion position. The knee-joint is not locked but is controlled by a connecting bar from the pelvis to the knee-joint.

portion of the pelvis, whereas the movements of the stump are independent of the pelvis and consequently of the basic principle of weight-bearing. In these experiments the shaft is cut through immediately below the uppermost portion of the thigh piece, and the lower part of the shaft can then be put into a position corresponding to the position of the stump, without this affecting the position of the ischial tuberosity. The results obtained up to now reveal a remarkable freedom from pressure in the area of the upper thigh piece, but nothing final can yet be said.

So far I have reported the most important things about our methods of construction, and I hope that the reader has understood my statements. I have concentrated intentionally on the essential features which are characteristic of our methods of fitting and construction, and have not mentioned details which I consider to be of secondary importance. I have also deliberately avoided the question of the expediency of prostheses. This point can perhaps be dealt with in later discussion.

At the conclusion of my statements, however, I should like briefly to mention knee- and foot-joint constructions, because I am of the opinion that a prosthesis which is satisfactory statically and in motion can still be further improved by the use of suitable joint constructions.

There has always been a demand for greater safety in artificial knee-joints. In 1916 Prof. Schede and my father made the first attempt to use hip extension mechanically for knee extension. It actually was possible to control the knee-joint by this means. But many other difficulties prevented further pursuit of this idea.

This experiment showed, however, that the safety of the knee-joint construction must be independent of the muscles acting at the hip. The principle of a knee-brake also was rejected as a solution, since the knee, in falling, is bent and does not bear weight. But if the brake does function in spite of this, the fall with the stiffened knee-joint is all the more violent.

The result of these considerations was the physiological gliding joint according to the principles of Dr. Schede-Habermann, which through the particular form of the joint condyles affords far greater security as regards weight bearing in the free knee movement. The peculiarity of this construction is that together with blocked dorsi-flexion of the foot-joint the mechanical point of support moves backwards horizontally, so that there is no tilting in the sense of a spontaneous and uncontrolled flexion or extension. The pelvis too maintains its normal movements when the amputated person walks.

There is no doubt that even if anatomic contours are imitated, the construction of artificial knee joints is still hindered by the fact that it is not possible with the means available to orthopedic technicians to reproduce joint surfaces, the ligamentous apparatus and the muscles.

This conviction led therefore to the construction of the toothed wheel segment knee joint, which is not identical with anatomic contours. When the knee joint is flexed 2 toothed segments, each with a different radius, turn against each other, the point of contact of the two segments quickly moving backwards, so that the prosthesis is flexed, but in the static phase remains capable of bearing weight because of the return of the point of contact. Since there is no friction involved the knee joint can be easily guided and controlled by the active forces of the stump. Owing to its construction the joint reacts quickly to all movements of the stump. The swinging and natural pendulum movement of the leg is deliberately accelerated by the toothed segments, so that no delay is caused when the amputated person takes a step. Rubber bands or springs to accelerate the movement of the joint are not necessary. This joint, which outwardly has no similarity with the natural

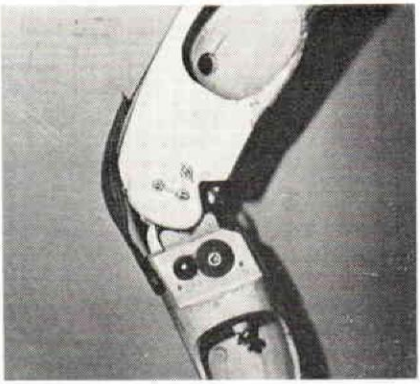

Figure 19. The physiological knee-joint as designed by Dr. Schede-Habermann.

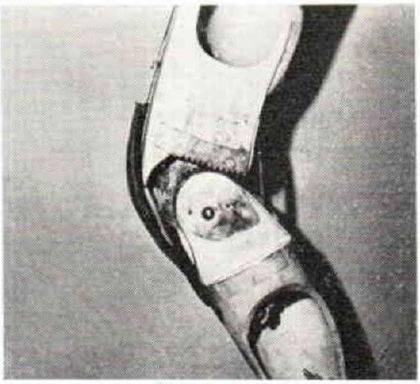

Figure 20. The toothed-segment knee-joint in flexion position. The toothed-segments are rolling against each other in backward direction and thus offer knee security also in the flexion position.

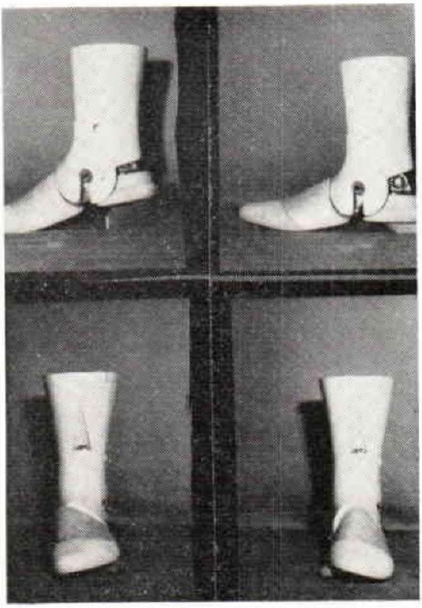

Figure 21. As a supplement to the knee construction we employ a foot technique in which the foot position can be adapted to the requirements of the gait as well as to the heel height of the shoe. This foot construction makes up for unevenness of the ground through supination or pronation of the forefoot. As consequence of this, no cants occur which may have any disadvantageous effects on the tuber seat.

knee-joint, nevertheless affords the amputated person the greatest safety in walking and standing as well as freedom of movement of the joint, that is, without braking and locking. Together with a good and individually constructed shaft such knee constructions are capable, in our opinion, of giving the wearer a maximum of prosthetic quality.

With these last statements I will close my report, and hope that I have given you an idea of our theories in the technique of prosthesis construction. For lack of space my statements are necessarily incomplete and only represent our personal view. I have not mentioned the use of either synthetic products or plastic materials, since it is a matter of course that every progressive firm today considers this question. For the most important elements of prosthesis construction, however, that is, fitting, statics, and function.

Orthopedic technique has a responsible task to fulfill in providing prostheses for persons who are physically handicapped or injured in accidents.

Every effort must therefore be made to give these people the feeling that they are again useful members of human society.