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ABOVE-KNEE PROSTHESIS SC-75

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To improve the function of above-knee amputees during walking, we focused on some problems relative to the design of an above-knee prosthesis with particular regard to:

- Conditions of stability during heel-contact, the stance phase, and push-off.
- The kinematics of the prosthesis during swing phase with particular reference to the minimum height of the trajectory of the foot above the floor.

The result is the prosthesis SC-75 shown in Figures 1 and 2.

The mechanism (Fig. 3) is composed of two coaxial tubes "A" and "B" which slide freely upon each other, being guided by bushings of a material with a low coefficient of friction. The external tube "A" is connected to the socket by the two connecting links "C"; the rod "B" is connected to the base of the socket by a hinge; the foot is hinged to member "A" at point "F" and is connected to "B" by the hinge "G" through the ball-and-socket joint "E." A plastic spring "H" provides for adjustment of the stroke of "B" with respect to "A." Knee flexion of 45 deg. produces about 20 deg. of dorsiflexion.

The mechanics of the prosthesis givês the possibility of improved function, including automatic lock of the knee joint and possible adjustment of the foot when it is not on center.

The prosthesis shown in Figure 1 is complete including a device for rotation of the foot about the vertical axis during stance phase. The "rotator" uses a spring of Neoprene installed below the knee joint.

To analyse knee stability during the stance-phase and push-off, we consider a hip-moment, M_H, of zero (Fig. 4), and consider as an index of prosthesis stability the length "E," which is related directly to the ratio between the moment necessary to flex the knee joint and the applied load.

The magnitude of "E" corresponds, in a single-axis-type prosthesis, to the distance between the

Fig. 1. Prosthesis Rizzoli SC-75.

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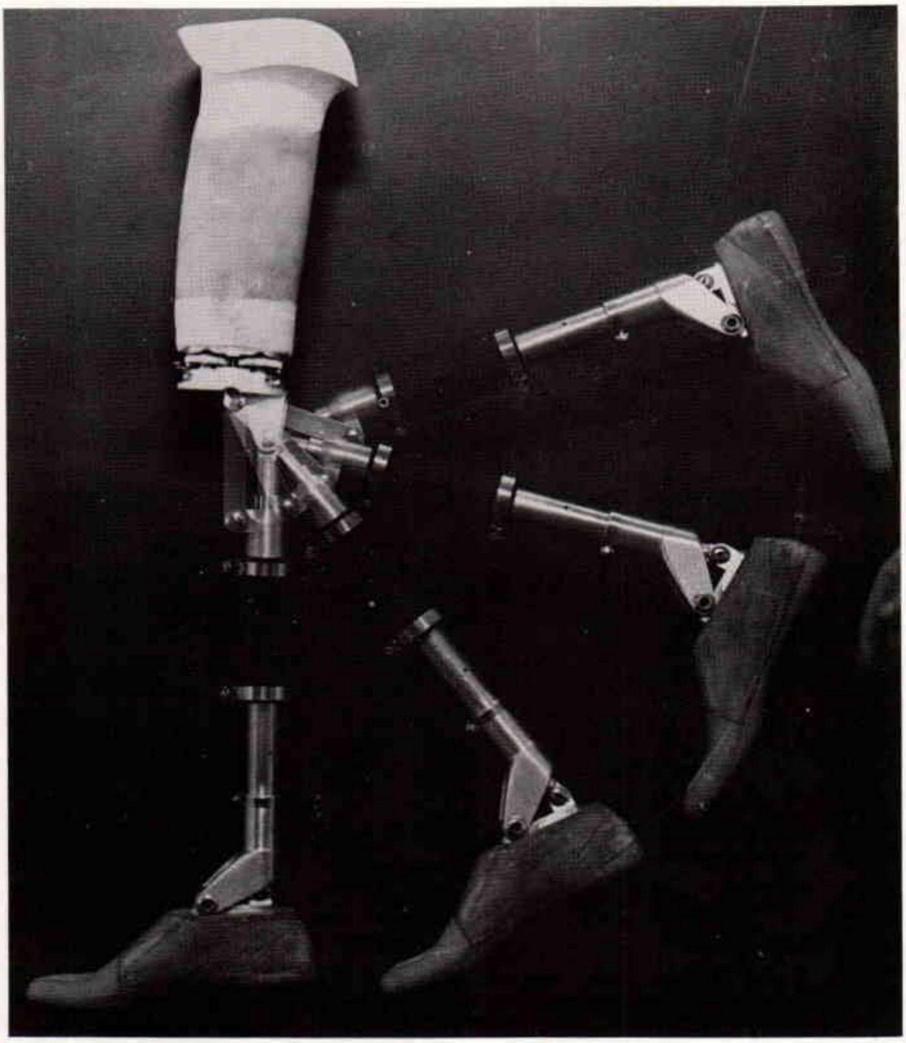

Fig. 2. SC-75 mechanism in different positions of flexion.

weight-bearing line and the center of the knee axis (Fig. 4). In a polycentric-type knee, "E" is measured from the instant center of rotation to the weight-bearing line.

In the SC-75 the moment at the knee joint is obtained by summing up the moment given by the axial load on the joint and the moment transmitted from the ankle joint to the knee joint. The second moment is a function of the distance between the center of joint "F" and the weight-bearing lines (Fig. 5).

The moment is a function of the distance "C" between the center "F" and the resultant floor reaction "R" and thus is dependent on the geometry of the ankle and knee-joint axes. Therefore it is possible to predict the function of the total knee assembly in providing better stability.

In comparison to the traditional prostheses, a further variable has been added which makes it possible to obtain a desired function of "E" to give the proper resisting moment.

The stability of the knee joint in traditional single-axis prostheses when $M_H = 0$ increases gradually with the movement of loads from the

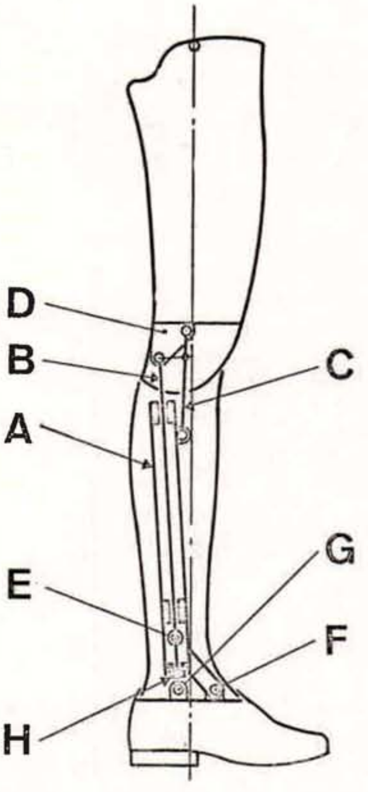

Fig. 3. Schematic diagram of the SC-75 prosthesis.

heel to the ball of the foot. This causes "over-stability" and therefore difficulty in initiation of flexion at push-off just before the beginning of swing phase. This undesirable characteristic can be reduced with a higher instant center of rotation, bringing it nearer the center of the hip joint (*1*). Devices which provide this possibility constitute a remarkable contribution to the improvement of walking, but only amputees with stumps able to exert sufficient moments of hip extension can profit from these devices because the stability is controlled by this moment, and the value of "E" is very low or possibly is negative.

With regard to the present SC-75 prosthesis, we have obtained, by a particular geometry of the joints of the mechanical structure, a design which is characterized by a high value of stability at heel strike and during midstance phase, and of which, as the load moves towards the ball of the foot, the stability becomes zero and subsequently negative.

In this way, control by the stump at push-off is possible without compromising stability in other conditions. For a better explanation of this concept, please refer to Figures 4, 5, and 6 which show the values of eccentricity "E" and distances "C" which are determined by the projection of the ankle joint on the floor and the weight-bear-

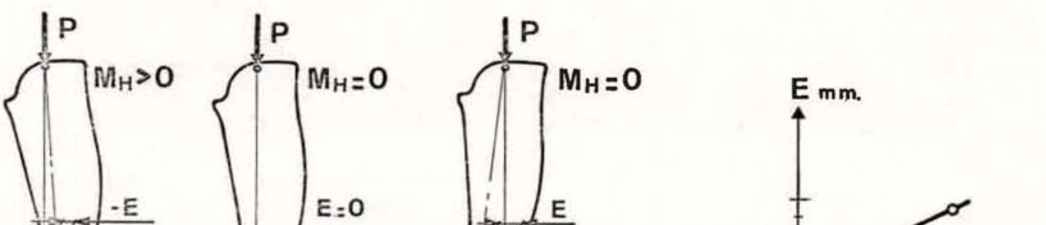

Fig. 4. Diagram of the stability index "E" for a single-axis type of prosthesis. C is the distance of the load axis from the ankle joint; E is the distance of the same axis from the center of rotation of the knee joint.

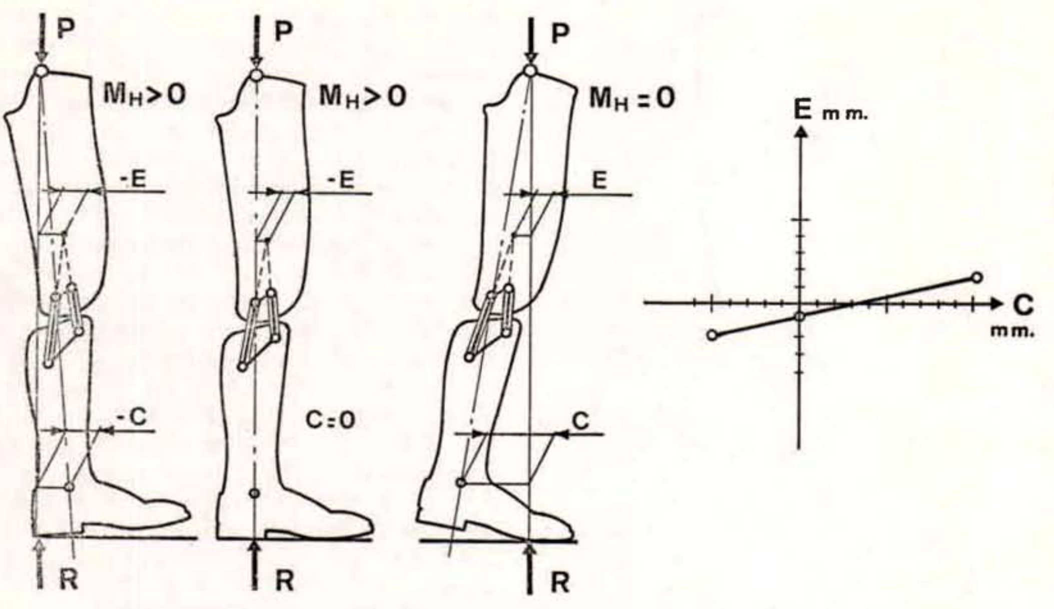

Fig. 5. Diagram of the stability index "E" for a polycentric type of prosthesis. See Fig. 4.

ing line. The diagrams show clearly the characteristic of the prosthesis SC-75 which results in optimum stability and ease of transition from heel contact to swing phase.[2]

Kinematics during the swing phase of the prosthesis has been carefully studied also. The design is so as to have the centers of relative motion between leg and socket (Fig. 7) quite similar to the physiologic centers in the knee in order to give an aesthetic and natural gait (*2*), but above all we obtained a very important characteristic necessary for correct, steady walking; dorsiflexion of the ankle in coordination with knee flexion. In this way the foot maintains a position parallel to the floor during the entire swing phase. The paths of the extreme points of the prosthesis give maximal distances from the articular coxofemoral center, lower than that provided by other types of single-axis prostheses (Fig. 8).

All this is helpful to the amputee during swing phase while negotiating uneven ground, because he can avoid lifting the hip thus acquiring an easier gait. Locking in full extension, at the end of the swing phase, is made possible by a plastic spring that is compressed at the beginning of the weight-bearing phase. Dynamic loads on the heel increase the joint stability. The same spring acts to limit the stroke in flexion to 115 deg.

A complete investigation on the validity of this prosthesis compared with traditional designs, and above all an investigation to define the problems of optimum conditions in the designing and manufacturing of a prosthesis, is going on in cooperation with Dr. Ing. Leo of the Centro di Automatica of C.N.R. in Rome and with Dr. Ing. Cappozzo of the Institute of Human Physiology at the University of Rome. The object of this research is to point out the kinematic and dynamic conditions of the prosthesis in different phases of walking and to try to determine which parameters are to be examined to define better the degree of perfection obtained in the different types of prosthesis.

[2]A different criterion in evaluating our prosthesis SC-75, particularly useful in a graph-design of the prosthesis, consists of determining the instant center of rotation of the foot in reference to the socket. This will be situated on the straight line that joins the instant center of the knee joint and the center of the joint "F." The distance from "F" will be

$$r = \frac{r_1}{1 - \frac{a}{b}}$$

in which r_1 is the distance between the knee instant center and F, a and b are the distances from the axis of tube B, from the knee instant center and from F. In this device the said instant center of rotation will be in a more elevated position and backward with respect to the coxofemoral joint.

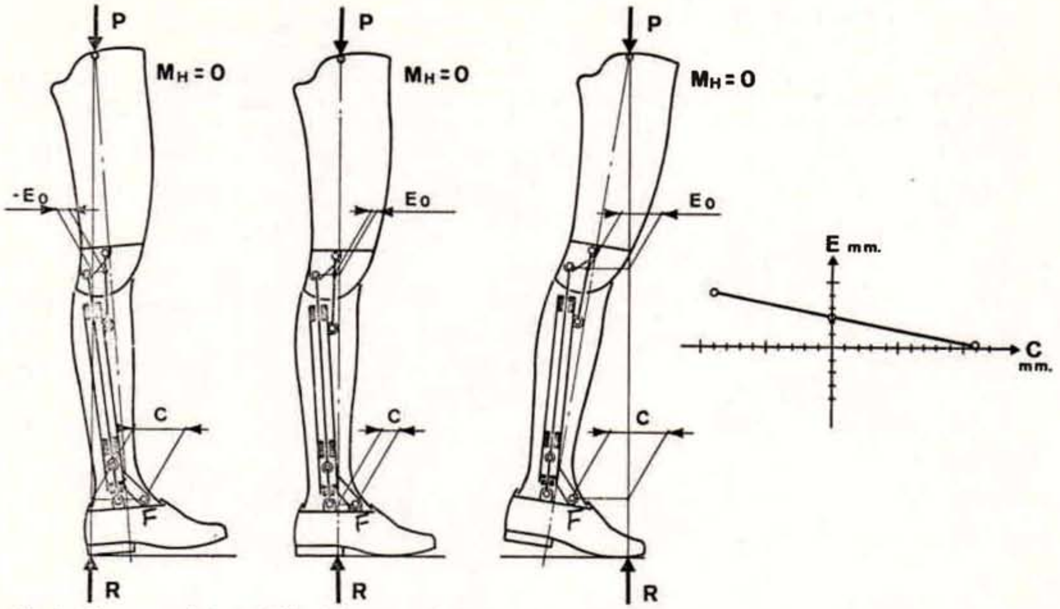

Fig. 6. Diagram of the stability index "E" in SC-75 prosthesis. The values of C are always the distances of the load axis from the ankle joint, whereas the value of E is the result of an expression like: $E = Eo - \Phi C$ in which Eo is the distance from the load axis to the articular center of the knee and the values of ΦC are such that they cancel E when the load axis moves to the ball of the foot.

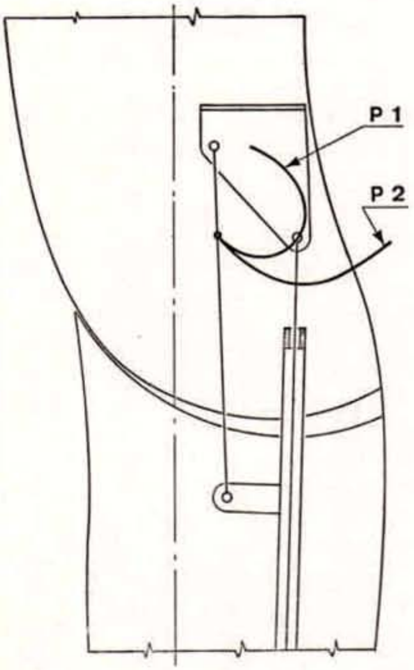

Fig. 7. Centers of relative motion between leg and socket.

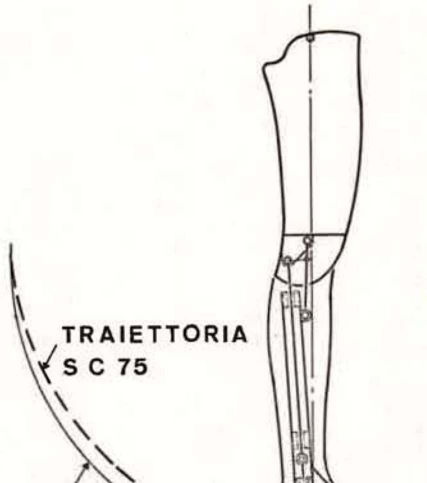

Fig. 8. Comparison of the trajectory of the external point of the foot of a single-axis prosthesis with that of the external point of SC-75. The dorsal flexion of the foot increases the distance from the floor during swing phase.

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