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Roentgenological Study of Certain Stump–Socket Relationships in Above-knee Amputees with Special Regard to Tissue Proportions, Socket Fit and Attachment Stability

UNO ERIKSON and URBAN JAMES

Departments of Diagnostic Radiology and Orthopaedic Surgery, University Hospital, Uppsala, Sweden

ABSTRACT

Twenty-five healthy active male above-knee amputees were studied. They had been uniformly fitted with their prosthesis, which in all cases had a total-contact suction socket of laminated plastic, and their walking capacity with the prosthesis was good. Sixteen of the patients were studied with respect to tissue proportions in the stump and intact thigh, while all 25 underwent studies concerning socket fit and relative movement between femoral stump and socket.

Mean total cross-sectional area of amputation stump 5–10 cm above end of femur was calculated to be 63% of that of intact thigh. Mean cross-sectional area of skin and subcutaneous tissue of the stump exceeded that of intact thigh by 12% ($0.01 > P > 0.001$). Muscle and bone tissues of stump were 55% ($P < 0.001$) and 27% ($0.01 > P > 0.001$) less, respectively, than those of intact thigh. In the stump, skin and subcutaneous tissue were calculated to occupy a mean of 41.8%, muscle 53.9% and bone 4.3% of the total cross-sectional area. Corresponding tissue proportions in intact thigh were 21.3%, 75.0% and 3.7%.

In only about 40% of the patients was contact between stump and socket actually total. In the remainder there was a free space of varying size at the distal end between stump skin and socket.

The femoral stump showed appreciable movement in the soft tissues within the socket. An arc of considerable dimension at the level of the knee and of the sole of the foot corresponded to observed changes in angulation of the femoral stump within the socket. On full weight-bearing on the prosthesis alone the distal end of the femur assumed its most distal, lateral and posterior position, obviously as a result of active muscular function for achievement of lateral stabilization of the pelvis and prevention of flexion (collapse) of the prosthetic knee joint.

INTRODUCTION

Despite the obvious drawbacks of any artificial leg in comparison with a natural, intact limb, the prostheses available nowadays for above-knee amputees in many respects give a satisfactory performance in walking, under favourable conditions.

A decisive factor for optimal utilization of the technical possibilities of a prosthesis is the stability of its attachment to the body. Questions associated with this factor are among the most important and at the same time the most difficult in the fitting of a prosthesis. The modern above-knee prosthesis (suction-socket type) is attached by an individually moulded socket, usually of plastic material, which it is intended shall enclose the stump with total contact. Weight-bearing takes place mainly against the ischial tuberosity, while the socket is retained on the stump partly by friction between the skin of the stump and the socket walls and partly by a negative pressure effect (1, 7). Thus for optimal function it is required that the attachment shall be as stable as possible, both for control of the prosthesis and for the transfer of power from stump to socket. It is generally considered that the longer the stump the better the prerequisites for achieving satisfactory anchorage of the prosthesis. However, the soft tissues of the stump also play a major role in this respect. The muscles, which in prosthetic gait seem to retain their pre-amputation pattern of activation in relation to the walking cycle (10), can on contraction cause a considerable change in shape of the stump, which is accentuated if the terminal muscle fixation to the bone is deficient. An excess of subcutaneous tissue causes too much relative movement between the femoral stump and socket, diminishing the stability of attachment of

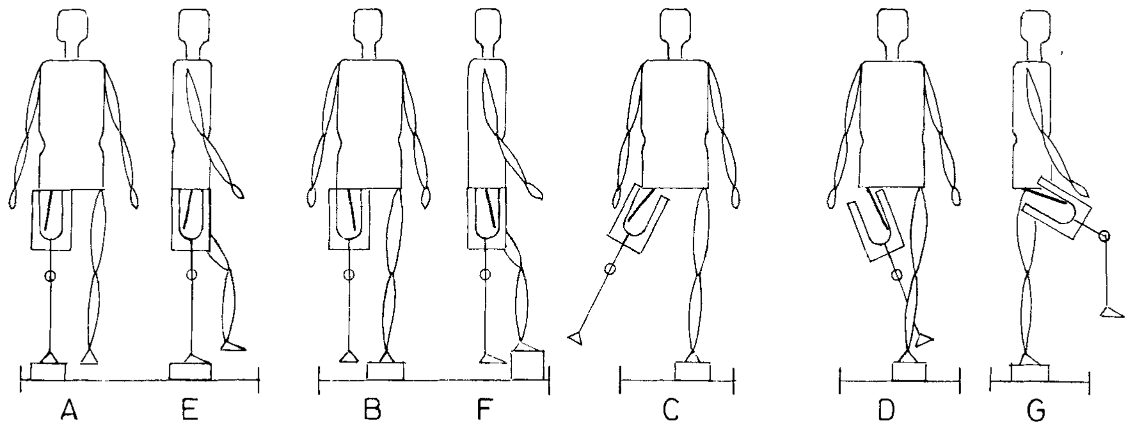


Fig. 1. Schematic illustration of the different study positions (A–G).

the prosthesis. A deficiency of soft tissue can cause pain. Further, skin with an unfavorably placed scar, possibly with depressions or adhesions to the bone, can create special problems related to the socket fit and attachment.

In the investigation described here roentgenological methods were used to study a group of well-rehabilitated active men with an above-knee amputation. The group was homogeneous with respect to post-amputation status and fitting of the prosthesis, which was of the suction-socket type. The aim was to study the proportions of skin and subcutaneous tissues, muscle and bone in the stump and intact thigh, with especial regard to muscular atrophy and to the proportion of subcutaneous tissue. A further aim was to evaluate the fit of the socket with respect to the desired total stump–socket contact, and the relative movement between the femoral stump and the socket.

MATERIAL

Twenty-five healthy, male above-knee amputees were studied. The group had been included in a material of patients described in detail elsewhere (5), for which they could be considered representative. Their age, height, weight and stump length and the duration since the amputation are presented in Table I. One of the patients had undergone amputation at 14 years of age, while in the others it had been performed after the end of the growth period. In only one patient had the myoplastic technique been used. All were considered to have been optimally fitted with modern prostheses, which were of the suction-socket type, i.e. prostheses with a laminated plastic socket, with a quadrilateral brim, which it was intended should enclose the stump with total contact, even distally (4).

All 25 patients were submitted to studies concerning the socket fit and the relative movement between the stump bone and socket, while only 16 of them were studied with respect to tissue proportions in the stump and intact thigh. The age, height, weight and stump length of these latter patients and the number of years since their amputation are given within parentheses in Table I. It can be seen in the table that the mean values and standard deviations and ranges for this group

Table I. *Age, height, weight (without prosthesis), number of years since the amputation and stump length (greater trochanter to distal end of femur) of the 25 patients studied with respect to stump–socket contact and the relative movement between the femoral stump and socket*

The figures within parentheses refer to the 16 patients who were studied with respect to tissue proportions in the intact thigh and stump

	M	S.D.	Range
Age, years	42 (43)	12 (12)	26–62 (28–62)
Height, cm	176 (176)	7 (6)	163–190 (163–190)
Weight, kg	69 (67)	10 (9)	49–83 (54–83)
Years since amputation	13 (15)	10 (10)	3–38 (3–38)
Stump length, cm	31 (31)	4 (4)	24–38 (25–38)

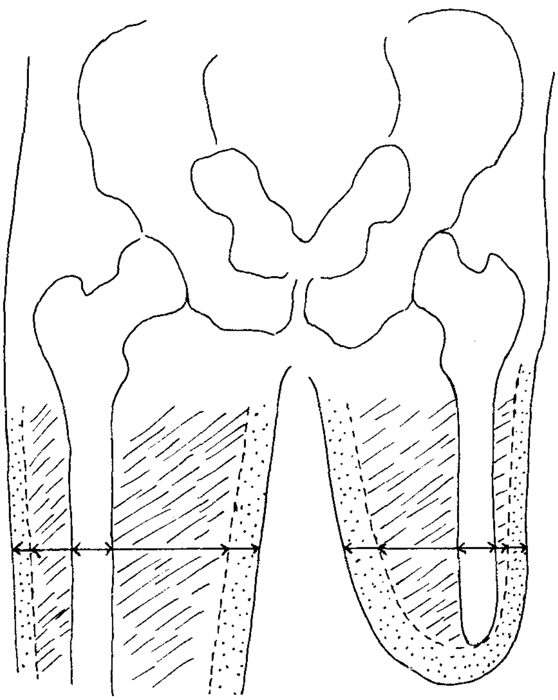


Fig. 2. Schematic illustration of measurement of the proportions of subcutaneous tissue (dotted), muscle (cross-hatched) and bone on the roentgenogram in the frontal projection.

differed only very slightly from those of the whole material. In both groups the mean stump length comprised about 65% of that of the intact femur.

METHODS

Roentgenological examination

The examinations concerning soft tissue evaluation were performed with the patient standing and with exposure according to the soft tissue technique (3) in the frontal projection, with the intact thigh and the stump on the same film.

The roentgenological examinations concerning socket fit and relative movement between the femoral stump and the socket were also performed with the patient standing, wearing the prosthesis. Exposures were made in the frontal and lateral projections, with different positions of the hip joint with and without weight-bearing (referred to in the following as "study positions"), that could be considered to represent situations in the use of the prosthesis.

Study positions (Fig. 1)

Frontal projection

A. Prosthesis bearing full body weight in neutral position.
B. Prosthesis bearing no weight in neutral position.
C. Prosthesis bearing no weight, actively abducted 30°.
D. Prosthesis bearing no weight, actively adducted 20°.

Lateral projection

E. Prosthesis bearing full body weight in neutral position.
F. Prosthesis bearing no weight in neutral position.
G. Prosthesis bearing no weight, actively flexed 60° with the prosthetic lower leg vertically dependent.

A dip circle applied on the prosthetic thigh was used for setting the position of the prosthesis at the respective examinations. Between each examination the patient stood for a few minutes on both legs before assuming the next study position.

The beam was directed horizontally with the film–focus distance 100 cm and the film cassette placed immediately behind the object.

Measurement on the roentgenograms

In calculating the tissue proportions in the stump and intact thigh a measurement was made, at the same level on both sides, of the total diameter of the stump and of the intact thigh, the diameter of the muscle providing the configuration and the diameter of the femur (Fig. 2). That level was chosen at which the muscle contour in the stump was still conical immediately above the area where it was rounded off distally. This level lay 5–10 cm above the end of the femoral stump. Under the assumption that the squares of the diameters corresponded to the cross-sectional area of the respective tissues and that these tissues were of the same shape, the proportions of the different tissues in the stump and intact thigh were calculated. From these measurements the proportions of skin and subcutaneous tissue could also be calculated (confer Erikson (2)).

Any unoccupied space between the distal socket wall and the skin of the stump was noted. The length of the space and its greatest width were recorded (Figs. 3 and 4).

From a chosen reference point on the distal end of the femur a measurement was made of the distance to the level of the bottom of the socket and also, in the lateral projection to the anterior and posterior walls of the socket (Fig. 5) and, in the frontal projection, to the lateral and medial walls, parallel to the level of the bottom. Furthermore, the change in angulation of the femoral stump in the socket between different study positions was measured. The distances measured on the roentgenograms are presented in the following Results section without correction for the magnification effect, which was calculated to amount to about 10%.

In the statistical analysis the arithmetic mean value (M) and standard deviation (S.D.) were calculated. Student's t-test was used for testing of significance (bilateral testing), and the following significance levels are given: $* = 0.05 > P > 0.01$; $** = 0.01 > P > 0.001$; $*** = 0.001 > P$.

RESULTS

I. *Tissue proportions*

The mean total cross-sectional area of the stump in the 16 patients studied in this respect was calculated to be 63% of that of the intact thigh

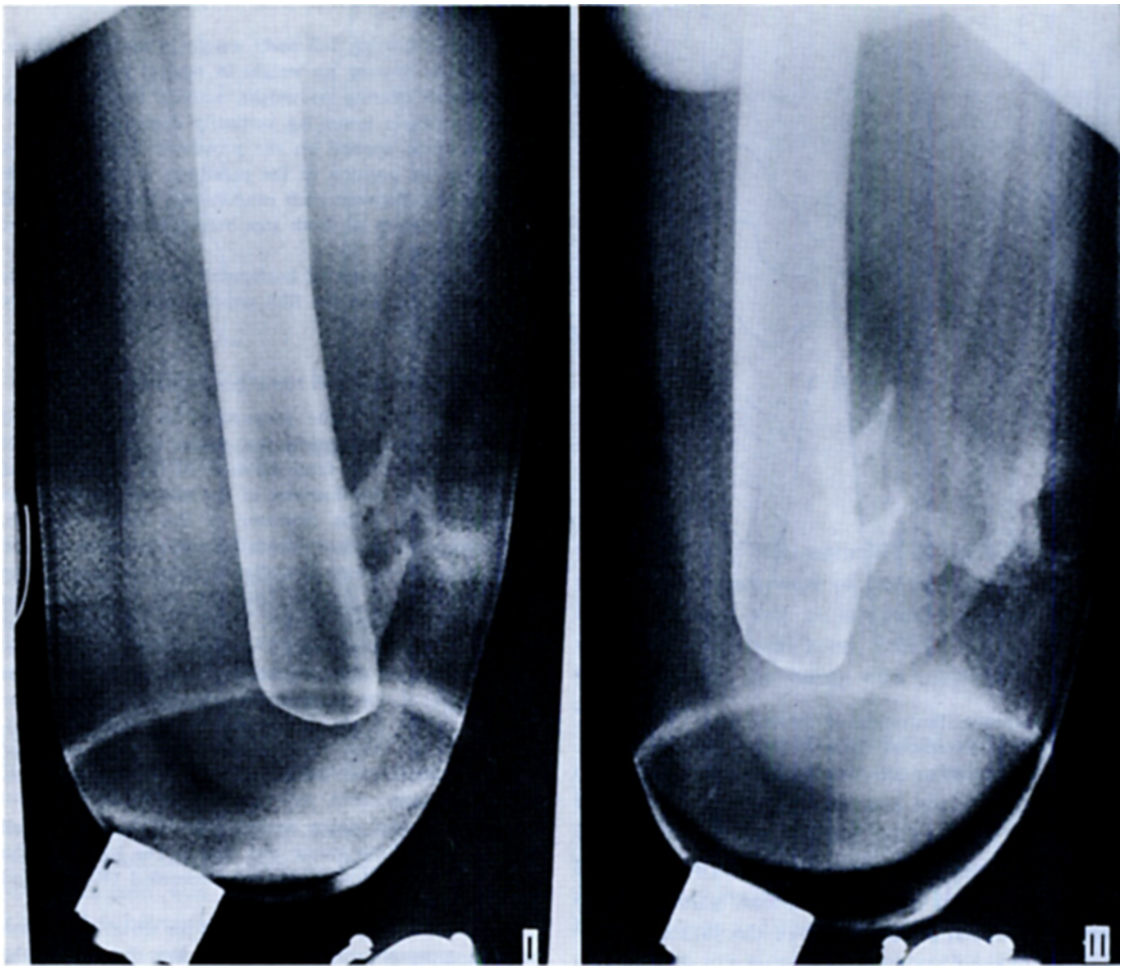


Fig. 3. Roentgenogram in the lateral projection. I: Prosthesis bearing full body weight in neutral position (study position E). II: No weight on prosthesis in neutral position (study position F). Note the position of the distal end of the femur and the shape and size of the free space. Note also the dorsally directed spurs on the femoral stump.

(S.D. 11, range 47–85). The tissue proportions in the stump and intact thigh can be seen in Table II. Muscle constituted a smaller proportion of the cross-sectional area in the stump (mean 53.9%) than in the intact thigh (mean 75.0%), in contrast to bone and especially skin and subcutaneous tissue, the proportions of which were greater in the stump (4.3% and 41.8%, respectively) than in the intact thigh (3.7% and 21.3%).

When the cross-sectional areas of the various tissues of the stump were expressed as percentages of the corresponding areas in the intact thigh (100%), as shown in Table III, it was found that the skin and subcutaneous tissue in the stump exceeded the same tissue in the intact thigh by an average of 12% ($0.01 > P > 0.001$). The areas of muscle and bone in the stump, on the other hand, were smaller than the corresponding areas in the intact thigh by an average of 55% ($P < 0.001$) and 27% ($0.01 > P > 0.001$), respectively.

II. *Stump–socket contact*

In patients in whom the stump–socket contact was not total, a free space was seen on the roentgenogram at the distal interface between stump and socket. This space was usually crescent-shaped, but varied somewhat depending on the configuration of the stump.

During weight-bearing with the prosthesis in the neutral position total stump–socket contact was seen in 11 patients both in the frontal (study position A) and lateral projection (study position E).

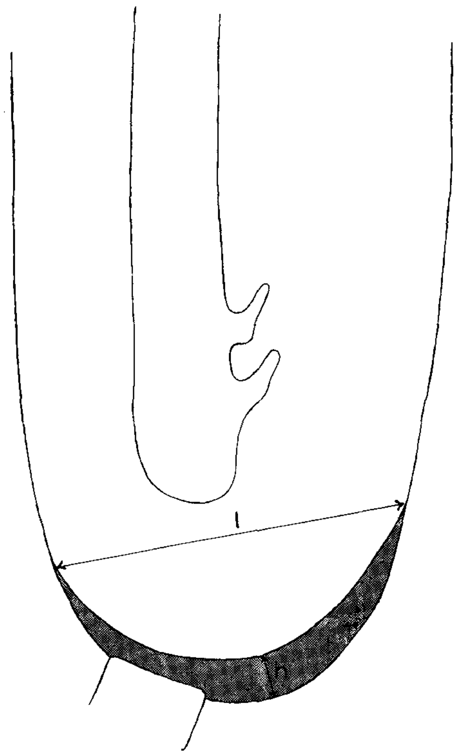


Fig. 4. Schematic illustration of the space in Fig. 3 II. *l*, length of space; *h*, greatest width of space.

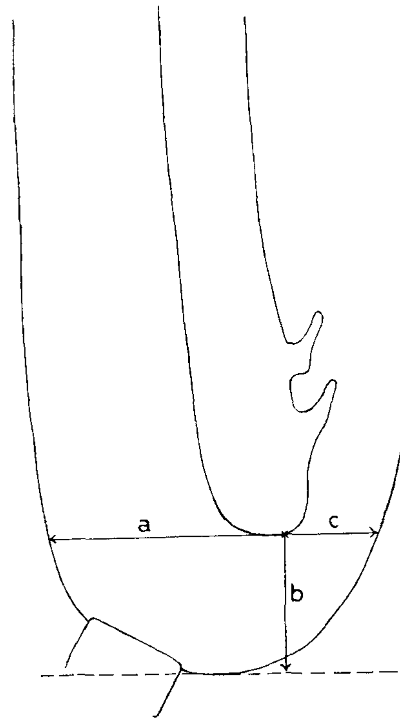


Fig. 5. Schematic illustration of roentgenogram in Fig. 3 I. *a*, distance from the reference point to the anterior socket wall; *b*, distance to bottom of socket; *c*, distance to posterior socket wall.

In one patient a space was seen only in the lateral projection; its length was 72 mm and width 3 mm. In the other 13 patients a space was observed in both projections; the mean length in the frontal projection was 73 mm (range 44–110) and in the lateral projection 64 mm (range 37–108), while the mean width in the frontal projection was 8 mm (range 2–20) and in the lateral projection 6 mm (range 1–16).

With the prosthesis bearing no weight in the neutral position, total contact was observed in 7 of the 11 patients in both the frontal (study position B) and the lateral projection (study position F). In 3 patients a space was seen only in the lateral projection; its mean length was 50 mm (range 23–67) and width 6 mm (range 4–12). In the remaining 15 patients a space was seen in both

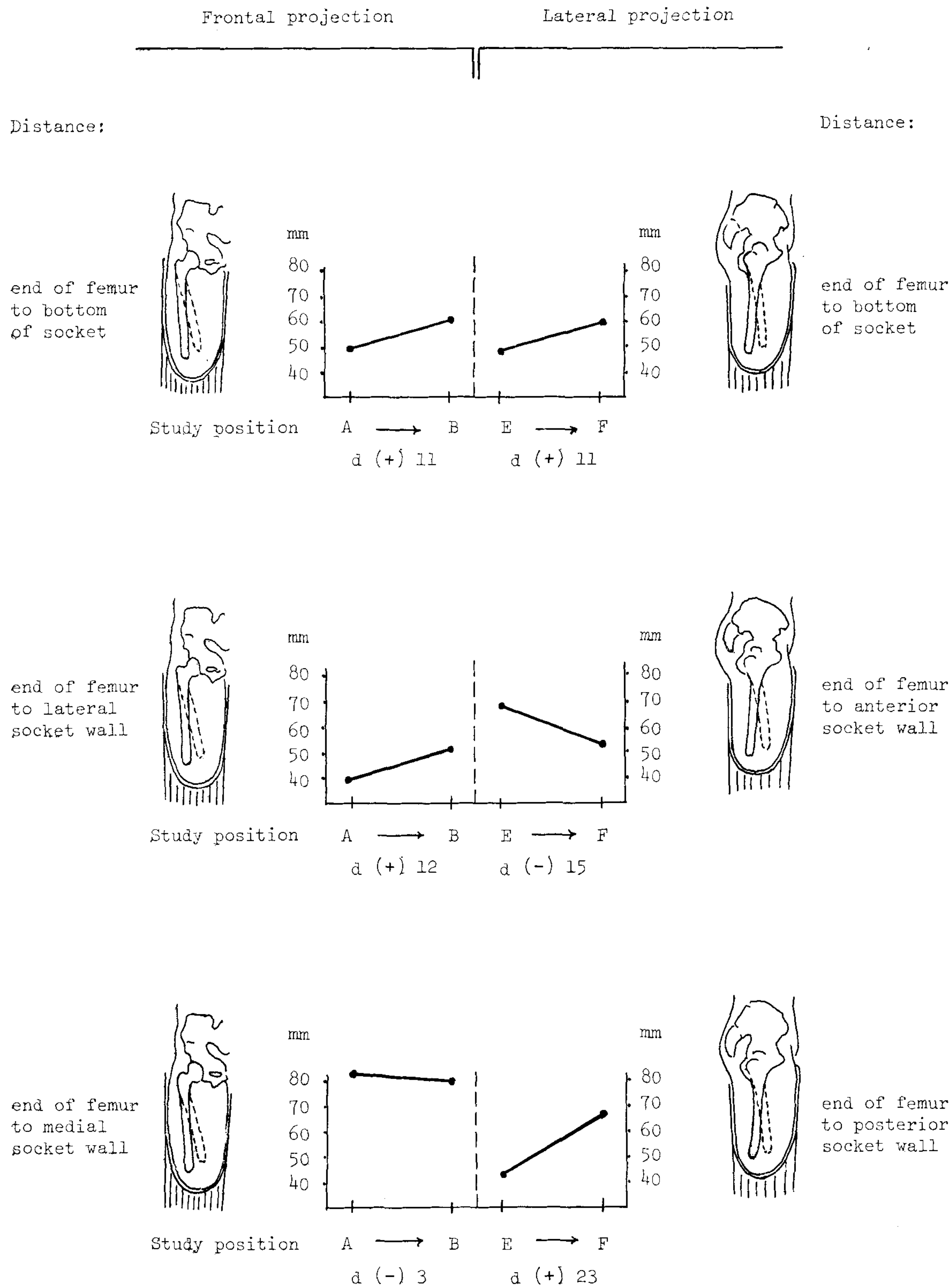
Table II. *Tissue proportions in the cross section of the intact thigh and stump in the 16 patients studied in this respect*

	% of cross-sectional area M(S.D.) range	
	Intact thigh	Stump
Skin + subcutaneous tissue	21.3 (5) 13–30	41.8 (9) 20–55
Muscle	75.0 (6) 66–85	53.9 (9) 41–73
Bone	3.7 (1.4) 2.4–6.9	4.3 (1.8) 0.4–6.8
	100 %	100 %

Table III. *Cross-sectional areas of the stump tissues in relation to the corresponding tissues in the intact thigh (100 %) in the 16 patients studied*

The total cross-sectional area of the amputation stump constituted, on the average, 63 % of that of the intact thigh

	Skin + subcutaneous tissue	Muscle	Bone
Intact thigh	100 %	100 %	100 %
Stump	112 %**	45 %***	73 %**
Range	77–200	30–80	32–136


Frontal projection
Lateral projection
Distance:
Distance:
end of femur to bottom of socket
mm
80
70
60
50
40
Study position
A → B
d (+) 11
E → F
d (+) 11
end of femur to bottom of socket
end of femur to lateral socket wall
Study position
A → B
d (+) 12
E → F
d (-) 15
end of femur to anterior socket wall
end of femur to medial socket wall
Study position
A → B
d (-) 3
E → F
d (+) 23
end of femur to posterior socket wall

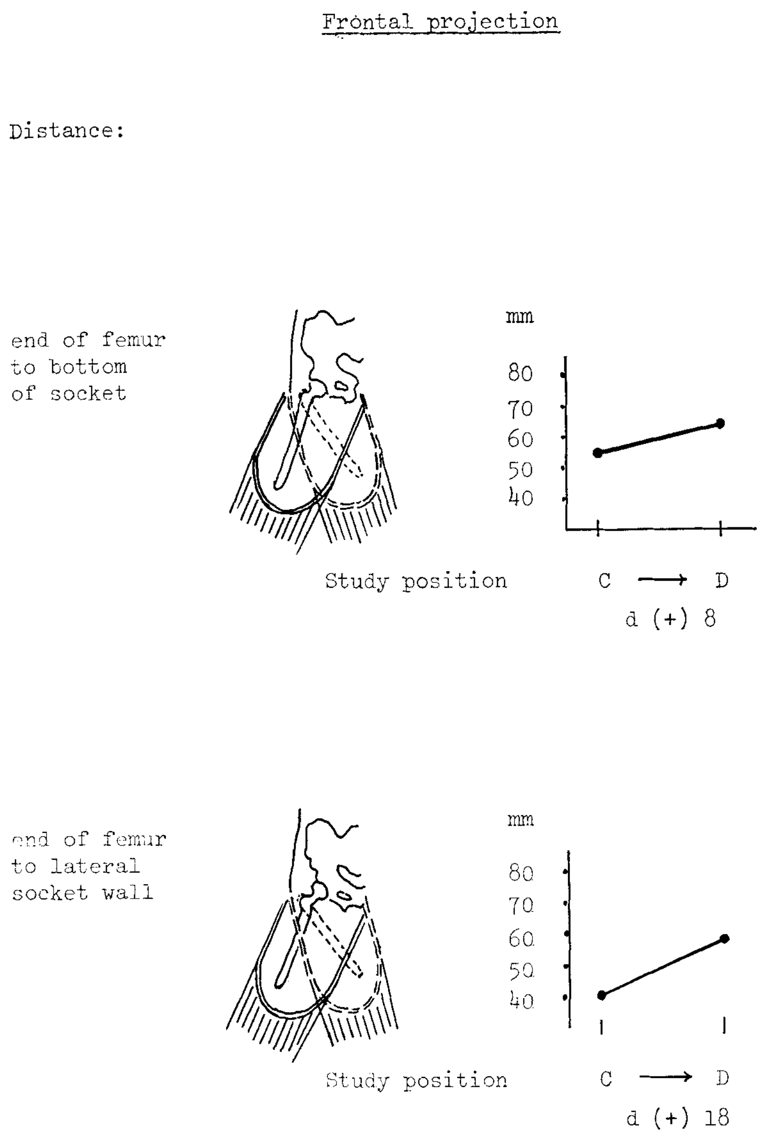


Fig. 7. Diagram illustrating the excursion of the distal end of the femur in the soft tissues within the socket between the indicated study positions in the frontal projection with the prosthesis bearing no weight and actively abducted 30° (C) and adducted 20° (D). The mean difference (*d*) between the respective study positions is given.

projections. The mean length in the frontal projection was 90 mm (range 45–130) and in the lateral projection 65 mm (range 28–130), while the mean width in the frontal projection was 9 mm (range 3–20) and in the lateral projection 8 mm (range 4–20).

Fig. 6. Diagram illustrating the excursion of the end of the femur in the soft tissues within the socket between the indicated study positions with the prosthesis bearing weight (frontal projection A, lateral projection E) and bearing no weight (frontal projection B, lateral projection F) with the prosthesis in the neutral position. The mean difference (*d*) between the respective study positions is given.

III. *Relative movement* (femoral stump–socket)

When the prosthesis bore full body weight (Fig. 1, study positions A and E) the mean distance from the reference point on the distal end of the femur to the bottom of the socket was 48 mm (range 8–55), while the distance to the lateral wall of the socket was 39 mm (range 10–67) and to the medial wall 82 mm (range 31–113).

The distance from the distal end of the femur to the anterior socket wall was 68 mm (range 20–128) and to the posterior socket wall 43 mm (range 18–73).

Table IV. *The change in angulation of the femoral stump in the soft tissues within the prosthetic socket between the study positions indicated, in the 25 patients studied*

Study position	Angle, degrees M(S.D.) range
A→B	2.6 (2.3) 0–9
E→F	5.0 (3.7) 0–13
C→D	4.8 (3.5) 1–16
E→G	11.3 (5.8) 1–26

Figure 6 (left side) illustrates a comparison, in the frontal projection and with the prosthesis in the neutral position, between the weight-bearing (study position A) and the non-weight-bearing prosthesis (study position B); on weight-bearing the distal end of the femur was 11 mm, on the average, nearer to the bottom of the socket, with individual variations up to 22 mm, 12 mm nearer to the lateral socket wall, with individual variations up to 30 mm, and 3 mm further from the medial wall, with individual variations up to 25 mm. The difference in displacement towards the lateral and away from the medial socket walls constitutes the difference in socket diameter at the level of the distal end of the femur in the respective study positions. Thus the socket diameter in the frontal plane at the level of the distal end of the femur was, on the average, 9 mm greater in the non-weight-bearing prosthesis than in the prosthesis bearing weight. When the same study positions (A and B) were compared with respect to change in angulation of the femoral stump within the socket (Table IV), the described displacements of the distal end of the femur corresponded to a mean angulation change of 2.6°, with individual variations up to 9°. The centre of rotational movement of the femoral stump within the socket was found to lie, on the average, approximately at the level between the distal and middle thirds of the socket.

Figure 6 (right side) illustrates a comparison, in the lateral projection and with the prosthesis in the neutral position, between the weight-bearing (study position E) and the non-weight-bearing prosthesis (study position F); on weight-bearing the distal end of the femur was 11 mm, on the average, nearer to the bottom of the socket, with individual variations up to 22 mm, 15 mm further from the anterior socket wall, with individual variations up to 43 mm, and 23 mm nearer to the posterior wall, with individual variations up to 53 mm. The difference in longitudinal level of the end of the femur between the respective study position thus corresponded, in the sagittal plane, to a mean change in socket diameter of 8 mm. When the same study positions (E and F) were compared with respect to the change in angulation of the femoral stump (Table IV) the mean angulation change was 5.0°, with individual variations up to 13°; here also the centre of rotational movement lay approximately at the level between the distal and middle thirds of the socket.

With the prosthesis bearing no weight and the prosthesis actively abducted 30° (Fig. 7, study position C) the mean distance between the reference point on the distal end of the femur and the bottom of the socket was 56 mm (range 33–154), while the distance to the lateral socket wall was 40 mm (range 18–69) and to the medial wall 87 mm (range 47–114).

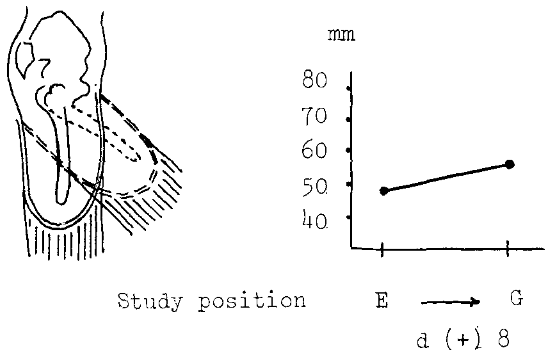
On comparison in the frontal projection (Fig. 7) between the prosthesis actively abducted 30° (study position C) and the prosthesis actively adducted 20° (position D), it was found that on abduction the distal end of the femur lay, on the average, 8 mm nearer to the bottom of the socket, with individual variations up to 26 mm, and 18 mm nearer to the lateral socket wall, with individual variations up to 49 mm. When the same study positions (C and D) were compared with respect to change in angulation of the femoral stump within the socket (Table IV), the described displacements of the distal end of the femur corresponded to a mean angulation change of 4.8°, with individual variations up to 16°; here also the centre of rotational movement lay, on the average, approximately at the level between the distal and middle thirds of the socket.

Figure 8 illustrates a comparison in the lateral projection between the weight-bearing prosthesis in the neutral position (study position E) and the prosthesis actively flexed 60° (study position G). In the former position the distal end of the femur lay, on the average, 8 mm nearer to the bottom of the socket, with individual variations up to 26 mm, 31 mm further from the anterior socket

Lateral projection

Distance:

end of femur to bottom of socket



end of femur to anterior socket wall

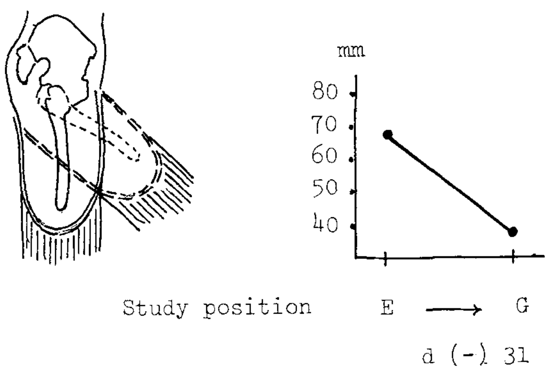


Fig. 8. Diagram illustrating the excursion of the distal end of the femur in the soft tissues within the socket between the indicated study positions in the lateral projection with the prosthesis bearing full weight in the neutral position (E) and actively flexed 60° (G). The mean difference (*d*) between the respective study positions is given.

wall, with individual variations up to 87 mm, and 35 mm nearer to the posterior wall, with individual variations up to 65 mm. A comparison of the same study positions (E and G) with respect to change in angulation of the femoral stump showed, as seen in Table IV, that the described displacements corresponded to a mean angulation change of 11.3°, with individual variations up to 26°; here again the centre of rotational movement lay, on the average, approximately at the level between the distal and middle thirds of the socket.

A study was made of possible correlations between the excursions of the femur within the socket and other variables, such as stump length and stump circumference, stump–socket contact, gait asymmetry (duration of stance and swing phases and step length for intact leg and prosthesis; bending of the trunk laterally) and walking speed. No statistically significant correlations were found, however, except between stump length and movement of the femur between study positions C and D (no weight on prosthesis in 30° abduction and 20° adduction, respectively). This correlation could be regarded as linear and corresponded to a correlation coefficient of 0.67 ($P < 0.001$).

DISCUSSION

I. *Tissue proportions*

The method used in this study to estimate the cross-sectional area of the stump and of the respective stump tissues solely from the diameter in the frontal plane is relatively crude, and the results must therefore be evaluated with some reservation (confer Erikson (2), Jones (6) and Marvin et al. (8)). Furthermore, the possibility of a deforming effect of the socket on the stump must be taken into account.

To judge from the tissue proportions the total decrease in volume of the thigh after the amputation is mainly due to the considerable muscular atrophy that occurs, and which amounts to an average of about 55%. Inactivity, chiefly resulting from loss of the knee, is probably the principal cause of this atrophy, but other factors may also be contributory, such as unsatisfactory terminal fixation of the muscles or alterations of the local circulation (2), or neurophysiological changes (10).

A striking finding was that on the average the stump had almost twice as great a proportion of skin and subcutaneous tissue as the intact thigh (41.8 and 21.3%, respectively). The skin must have been of about the same thickness on the two sides, and the difference must therefore lie with the subcutaneous tissue. In relation to the intact thigh there was a significant mean increase in subcutaneous tissue by about 12% after the amputation. Factors such as continuously varying pressure of the socket on the stump and excursions of the femoral stump within the soft tissues on walking may possibly contribute to the development of hypertrophy. From the aspect of fixation of the prosthesis to the body, however, this increase in subcutaneous tissue is unfavorable, as the soft, compliant and formable subcutaneous fat must impair the stability.

The femoral (bone) proportion of the stump cross-section increased somewhat after the amputation as a result of the total reduction in volume of the stump, but decreased in relation to the cross section of the intact femur by an average of about 27%. Relief of the femoral stump from most of the weight-bearing by the use of an above-knee prosthesis and the less active role of the femoral stump in comparison with the femur of the intact leg probably explain this bone atrophy.

Erikson (2), using the same method as has been used here, studied the tissue proportions in the stump and intact thigh in 11 male above-knee amputees, with special regard to the muscle and its blood flow. In comparison with the material of the present study he found essentially corresponding tissue proportions in the intact thigh but in the stump a somewhat greater proportion of muscle and smaller proportion of subcutaneous tissue. Further, he reported greater individual variations. He did not relate the stump tissues to corresponding tissues in the intact thigh, as in the present study. The differences between the mean values and ranges of this material and those of Erikson can be explained by the more heterogeneous composition of Erikson's material.

Sevastikoglou et al. (9) studied the bone density and the thickness of the cortical bone in above-knee and below-knee amputees and found that in comparison with the intact side the bone of the stump had undergone atrophy with a decrease in both density and cortical thickness as a result. These findings are thus in agreement with the considerable bone atrophy observed in the femoral stump in the present study.

II. *Stump–socket contact*

There appeared to be total contact between the stump and the socket in about two-fifths of the patients, i.e. no free space was observed in these cases. Of the other three-fifths, the somewhat larger space that was noted when no weight was placed on the prosthetic leg than when it carried the full body weight was probably due mainly to a larger air volume caused by reduced pressure and possibly also to some extent to the fact that the existing amount of air was accumulated in a smaller, more limited area between the stump and the socket wall at the distal end. It is probable that the amount of air would only exceptionally increase by inward suction between stump and socket wall. The relatively moderate free space that was observed in these three-fifths of the patients did not seem to increase the relative movement between the femoral stump and the socket, as mentioned above.

III. *Relative movement* (femoral stump–socket)

According to the measurements there was considerable excursion of the femoral stump in the soft tissues within the socket. Around the mean values, however, there were large individual variations. With the patient standing and bearing full weight on the prosthetic leg alone the distal end of the femur assumed its most distal position in relation to the socket, while the ischial seat of the socket brim was pressed against the ischial tuberosity, where most of the weight-bearing takes place. At the same time the distal end of the femur was pressed against the lateral wall of the socket, obviously through abduction, with the purpose of stabilizing the pelvis laterally and thereby preventing lowering of the contralateral half of the pelvis. In addition the distal end of the femur was also pressed dorsally against the posterior socket wall, obviously through active extension, in order to guarantee extension of the prosthetic knee.

With the patient standing and bearing full weight on the intact leg with the prosthesis dependent in the neutral position a true lengthening of the "prosthetic leg" (stump + prosthesis) took place as a result of excursion of the femoral stump in the proximal direction; after correction for magnification on the roentgenograms this lengthening amounted to an average of about 10 mm. At the same time the distances between the distal end of the femur and the lateral and posterior walls of the socket, respectively, increased—after correction for magnification by an average of about 11 and 13 mm. When the hip of the amputation side was then flexed with the prosthetic lower leg vertically dependent, there was further considerable ventral excursion of the distal end of the femur towards the anterior socket wall—after correction for magnification amounting to an average of about 14 mm.

On active abduction and adduction of the prosthesis (30° and 20°, respectively)—in a neutral position between flexion and extension—with no weight placed on that leg, examination in the frontal projection showed considerable lateral excursion of the distal end of the femur in the soft tissues within the socket; this was correlated to stump length. On adduction there was also longitudinal displacement of the prosthesis in the distal direction in relation to the femoral stump, obviously due to contact of the ischial tuberosity with the ischial seat of the socket. This resulted in further lengthening of the "prosthetic leg", which amounted to an average of about 7 mm after correction for magnification.

The greater diameter of the socket at the level where the distal end of the femur was located when no weight was borne on the prosthesis, compared with the diameter on weight-bearing, must have had an unfavorable influence on the attachment stability of the prosthesis.

The changes in angulation of the femoral stump in relation to the socket between different study positions appeared to have considerable significance with respect to attachment of the prosthesis, to judge by calculations of the arcs of the angles at the level of the knee and sole of the foot, on the basis of the observation that the centre of rotational movement of the femoral stump in the socket lay, on the average, approximately at the level between the distal and middle thirds of the socket. It was found that the arc length corresponding to the change in angulation between the weight-bearing and non-weight-bearing prosthesis in the neutral position in the frontal plane was, on the average, about 1.5 cm at knee level and about 4 cm at the level of the sole of the foot. In the sagittal plane the corresponding values were 2.5 cm and 7 cm, respectively. Between positions with 30° abduction and 20° adduction of the prosthesis with no weight on that leg, the arc length in the frontal plane was about 2.5 cm at the level of the knee and about 6.5 cm at the sole of the foot. Between positions when the prosthesis carried the body weight in the neutral position and when it bore no weight in 60° flexion, the change in angulation of the femoral stump in the sagittal plane corresponded to an arc length of about 6 cm at knee level. Also regarding these angular changes there was large individual variation around the mean values.

It is obvious that instability in attachment of the prosthesis to the stump, with the considerable relative movements that this entails, must affect the prosthetic gait, not least with respect to proprioceptive sensation of the position of the prosthesis. Factors causing individual variations of the excursion of the femoral stump in the soft tissues and socket include the shape, fit and alinement of the socket, the prosthetic knee's own stabilization capacity in the standing posture, the length of the stump and its soft tissue quality and the patient's individual way of influencing the prosthetic knee and achieving pelvic stabilization by active stump function with his own muscle power.

ACKNOWLEDGEMENT

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Address for reprints:

U. James, M.D.
Department of Orthopaedic Surgery
University Hospital
750 14 Uppsala, Sweden