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Patellar Tendon Bearing Suction Prosthesis

Clinical Experiences

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ABSTRACT

Clinical experiences from a trial of the PTB-suction prosthesis from 1969 to 1976 are presented. Forty-six patients tried the prosthesis and 26 adapted to it. The PTB-suction prosthesis has proved to be a satisfactory alternative for patients who easily develop skin lesions on the amputation stumps when using an ordinary PTB-prosthesis.

A modification of the patellar tendon bearing (PTB) prosthesis, named the PTB-suction prosthesis has been developed at the Orthopaedic Workshop (Een & Holmgren, AB Prosthetic Appliances) affiliated to the University Hospital in Uppsala, and was described in a preliminary report in 1971 (1). The clinical trial of this prosthesis began in 1969 at the Amputee Training and Research Unit (gåskolan) of the Department of Orthopædic Surgery. During the following years the prosthesis was included in functional studies of the below-knee stump. In one investigation the pressure variations in the socket of the prosthesis during walking were determined (2), and in a roentgenological study the relation between the amputation stump and the socket was examined at different static positions simulating stride components (3). To estimate the muscular activity of the amputation stump during walking with a PTB and a PTB-suction prosthesis an electromyographic investigation was carried out (4).

This prosthesis was constructed for those wearers of the ordinary PTB prosthesis who often sustained contact sores and skin irritation on the amputation stump. The idea was to immobilize the skin.

In this paper the collective clinical findings from a trial of the PTB-suction prosthesis during the period 1969–76 are presented. Three specific aims of the paper are to show:

1) How the PTB-suction prosthesis has managed contact problems on the amputation stump

2) What characteristics make an amputation stump suitable for the use of a PTB-suction prosthesis

3) How social and personality factors and previous adjustment to a prosthesis influence the adaptability to and usage of the PTB-suction prosthesis.

PATIENTS AND METHODS (TABLE I A, B)

Patients

Forty-six patients (mean age 49 years, range 4–84 years) with below-knee amputations (unilateral in 13 women and 32 men, and bilateral in one man) tried the PTB-suction prosthesis. Only patients who had tried the prosthesis for more than 2 months are included in this report. The interval between amputation and trial of the prosthesis varied between a few months and 61 years. In the majority of the patients testing the prosthesis the amputation had been performed because of trauma, but other reasons were diabetic or arteriosclerotic vascular diseases, congenital defects, tumour and osteomyelitis (Table II). This series of patients had been referred to the "Gåskolan" from many different hospitals. Thus the amputation technique varied considerably and it was therefore meaningless to try to evaluate the relation of this factor to the prosthetic suspension in general or to the PTB-suction prosthesis in particular. There was no occupational selection among the patients and thus there was a considerable variation between more active and sedentary occupations.

Technical comments on the prosthesis

The follow-up concerning the fit of the prosthesis was conducted in collaboration with a qualified prosthetist (L. Marsh). Initially the PTB-suction prosthesis was constructed with the socket and the rest of the prosthesis as one unit, and in this design the socket was rigid. Later the socket was made as a detachable semirigid component. These two different models are not evaluated separately in this presentation. The rigid socket version and its putting-on procedure have been described previously (1). The putting-on of the semirigid insert suction socket version is described briefly below.

The inner component—the semirigid insert suction

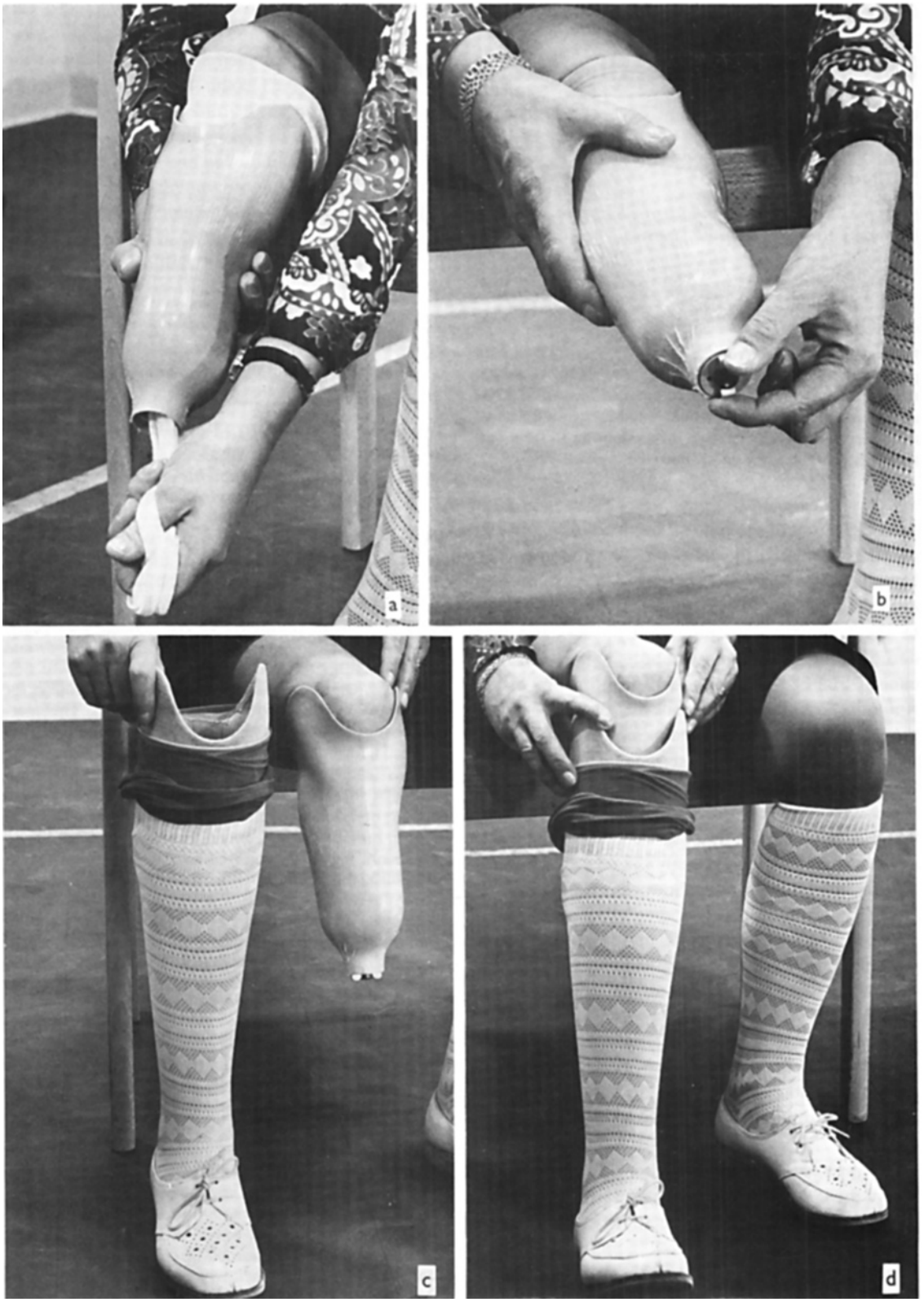
a
b
c
d

Fig. 1. The putting-on procedure for the PTB-suction prosthesis. The model with the semirigid insert suction socket is shown. (*a*) The soft tissues are pulled down and pre-stretched. (*b*) The valve is screwed into the semirigid insert suction socket while the stump is being pressed down inside it, and the valve is kept open. (*c*) The semirigid insert suction socket is ready to be put into the hard socket component of the prosthetic limb. (*d*) This is now done. (*e*) The prosthesis is ready for walking. Note the rubber sleeve around the socket opening. This reduces the possibility of air leaking into the socket.

socket—is the actual socket. It is put on the stump separately (Fig. 1). The stump is provided with a tubular stockinette. The distal end of the stockinette is pulled out through the hole for the valve. The stump is placed in the socket and at the same time the stockinette outside the valve is pulled. This brings the soft tissue into position in the bottom of the socket. The socket is well shaped to accommodate this accumulated tissue. The valve is threaded in while the stump is being pressed into the socket from the proximal direction. The stump fitted into the semirigid inner socket component, is then placed in the hard socket of the prosthetic limb. This hard socket has a rough inner surface which by friction keeps the semirigid socket in place.

Clinical data

The clinical follow-up of the patients using the PTB-suction prosthesis was carried out at intervals of one, three and six months, one year, and then once a year. The longest observation time is 7 years. The initial short intervals were necessitated by the soft tissue changes in the amputation stump, which meant that the socket often had to be changed for one of different size to ensure function.

Soft tissue changes constitute a well known problem with the ordinary PTB prosthesis, but are much more decisively disturbing functionally with the PTB-suction prosthesis.

When the patient received his first PTB-suction prosthesis the following measurements were made on the amputation stump.

1) The length of the stump (measured with a tape measure from the medial joint space to the end of the stump bone).

2) The stump periphery (circumferences measured at the level of the tibial tuberosity and at 5 cm below this point).

3) The amount of soft tissue distal to the end of the bone. (The soft tissue was carefully pulled down and the distance between the end of the tibia and the soft tissue end of the stump was measured with a tape measure. This amount of soft tissue was graded 0, +, and ++, where 0 <1 cm, + = 1–2 cm and ++ >2 cm.)

4) Skin lesions preventing the patient from wearing his prosthesis were graded + and ++, where + meant occasional lesions once or twice a year and ++ almost constant lesions.

5) Such factors as areas of sensory defects, frail skin, the location and state of the amputation scar and the length of the fibula in relation to the tibia were recorded.

6) Earlier adaptability to the ordinary PTB prosthesis and/or "conventional" prosthesis with side steels was recorded and graded +, 0, and − where + meant a satisfied patient, 0 meant undecidedness and − meant problems and dissatisfaction with the prosthesis.

At subsequent follow-ups the extent to which the PTB-suction prosthesis had been used was recorded, as well as the patient's sense of security with the prosthesis and the skin condition, with special regard to skin lesions.

The extent to which the prosthesis had been used was graded:

1/1, PTB-suction prosthesis used as the primary prosthesis

1/2, PTB-suction prosthesis used as an alternative (once or a few times a week)

−, Another prosthesis used entirely

In the following report the two former groups are denoted: "adaptable to the PTB-suction prosthesis" and the latter group "not adaptable to the PTB-suction prosthesis". See classification for adaptability below.

An additional inquiry was made in the autumn of 1976 to check how many of the initial wearers of the PTB-suction socket who were still using the prosthesis—compared with the figures in 1974. New wearers were not recorded now.[1]

[1] It may be of interest to note that since 1974 Een & Holmgren AB have made several PTB-suction prosthesis for patients from hospitals in the Stockholm region (Karolinska Hosp., Huddinge Hosp., Southern Hosp. and Danderyd Hosp.).

Table I A. *Data for patients adaptable to the PTB-suction prosthesis*

Name	Participation in earlier studies Ref. (1) Ref. (2) Ref. (3) Ref. (4)	Age	Occupation[a]	Sex	Reason for amputation[b]	Stump length (cm)	Stump periphery (cm)	Type of scar on stump end[c]	Location of scar on stump[d]	Fibula[e]	Skin lesion graded[f]
J. H.	1 2 3 4	52	A		T	19.5	27.5	La	M	E	–
H. H.	3	69	Se		T	15	29		M	S	+
H. L.	1 2 3 4	39	A		T	18.5	28	La	D	S	+
I. W.	3	40	A	♀	Tu	17.5	27	La	L	S	–
J. S.		58	H		Db	14.5	32	La	M	E	+
N. L.	3	36	A	♀	C	18	30	La	M	–	++
R. K.	1 2 3	43	A	♀	T	14	25.5	Sm	A	S	–
J. T.	3	31	H		T	18.5	28	La	D	E	++
K.-O. E. sin	2 3 4	46	A			17	24.5	Sm	M+D	S	–
K.-O. E. dx		46	A		T	18	25	Sm	M+D	E	–
S. D.	3 4	39	Se		C	12.5	27.5	Sm	M	S	+
G. K.	3	60	A		T	17	24.5	Sm	M	S	+
L. O.	3	37	Se	♀	T	13.5	25	La	D	–	–
K. M.	1 2 3 4	37	A		T	18	26.5	La	M	S	++
R. H.	3	50	Se	♀	V	14.5	27.5	Sm	M	S	+
H. G.	3	56	Se	♀	V	12.5	41	La	M	S	+
E. F.	3	49	A		T	17	30			S	+
S. N.[h]		42	A		O	14	31.5	Sm	M	S	+
R. E.		84	Se	♀	O	11	23.5	Sm	M	S	+
B. B.	1	27	A		C	15	31	Sm	A	S	+
E. N.		62	S		T	17.5	28	Sm	M	S	+
E. J.	4	55	H		T	22	30	Sm	D	S	–
B. L.		25	Se	♀	C	20.5	26.5	Sm	L	S	–
M. H.		4	A		C	(8)	(17.5)	Sm	A	S	–
L. B.		31	A		T	15	32	Sm	M	E	–
B. S.		38	Se		T	16.5	31	La	D	S	–
J. L.		64	H		Db	22.5	31.5	Sm	A	S	–
						M=16.19 S.E.=0.56 n=26	M=28.90 S.E.=0.73 n=26				

[a] H=Arduous labour. A=Active. Se=Sedentary.
[b] T=Trauma. Tu=Tumour. Db=Diabetes. C=Congenital defect. V=Vascular disease. O=Osteomyelitis.
[c] Sm=Smooth scar surface. La=Laciniated scar surface.
[d] M=On the tibial end. D=Dorsal. V=Ventral. L=Lateral.
[e] –=Absent. S=Shortened. E=Same length as tibia.

Statistical methods

Conventional methods (5) were used for calculating mean values standard deviations (S.D.) and standard errors of the mean (S.E.). Significance of differences between mean values were estimated by Student's t-test. The chi-square (χ^2)-test was used for comparing frequences. The statistical significance (p) was tested at the 0.05, 0.01, and 0.001 level.

RESULTS (TABLE I A, B)

Patients

The PTB-suction prosthesis was tested on 46 patients (47 legs) between 1969 and 1974. Twenty-six of them (27 legs) were classified as being adaptable to the new prosthesis and 20 as not adaptable (Table III). This classification was based on the patient's own statement regarding his or her ability to wear the prosthesis. Further, the patient had to have tried the prosthesis for at least 2 months. In 1976 the inquiry showed that 17 of the 26 patients were still using these prosthesis.

Among the 26 "*adaptable*" patients there were 19 who used the PTB-suction prosthesis daily as their primary prosthesis. Four of these had never tried any other prosthesis and the other 15 had changed from the ordinary PTB model. Of the 15 who changed, the reason in 10 was recurrent skin lesions. Five patients had a large excess of soft tissue distal to the bony end of the stump (>3 cm) and had suffered much instability and tenderness in the

Healing of skin lesions using PTB-suction prosthesis	Sensory distur-bances	Skin lesion in hollow of knee	Soft tissue below skeletal end[f]	Adaptability to PTB-prosthesis/ Conventional prosthesis[f]	The usage of PTB-prosthesis 1/1 or 1/2[f]	Used PTB-suction prosthesis (years)[g]	Interval (years) between amputation and trial of PTB-suction prosthesis	Lack of cooperation (Lc) or Addiction (Ad)
−	−	−	+	+/	1/2	4	2	−
−	−	−	++	+/	1/2	2 (4)	2	−
+	+	−	+	+/O	1/2	4	10	−
−	−	+	++	−/+	1/1	2 (4)	23	−
+	−	−	++	+/	1/2	2 (4)	4	Lc
+	−	+	++	−/	1/1	2 (4)	14	−
−	−	−	++	−/	1/1	5 (7)	1	−
+	−	−	++	−/−	1/1	4 (6)	4	−
−	−	−	++	+/	1/1	4 (6)	38	−
−	−	−	++	+/	1/1	4 (6)	38	−
+	−	−	++	+/+	1/1	1	12	−
−	−	−	+	+/−	1/1	4	10	−
−	−	+	++	−/O	1/1	2 (4)	21	−
+	−	+	+	O/	1/1	5 (7)	5	−
+	−	+	++	+/	1/1	2 (4)	5	−
+	−	+	++	O/O	1/1	2 (4)	27	−
+	−	+	++	−/	1/1	1 (3)	2	−
−	−	−	++	O/O	1/2	3	4	−
−	−	−	++	+/O	1/1	2	61	−
+	−	+	++	−	1/1	4 (6)	<1	−
−	−	−	0	O/+	1/2	3	33	−
−	−	−	0	+/+	1/2	3 (5)	13	−
−	−	+	++	+/	1/1	1 (3)	1	−
−	−	+	++	−	1/1	1 (3)	<1	−
−	−	−	++	−	1/1	2	1	−
−	−	−	++	−	1/1	1 (3)	<1	−
−	−	+	++	−	1/1	1	<1	−

[f] See text, under Patients and Methods.
[g] Figures in parentheses denote patients using PTB-suction prosthesis in 1976.
[h] This patient had angiographically verified vascular disease and in the few years before trying the PTB-suction prosthesis he had intermittent claudication symptoms from the amputated leg. The use of this prosthesis alleviated his symptoms.

ordinary PTB prosthesis. Two patients changed for cosmetic reasons alone.

Seven patients used the prosthesis as a change in certain circumstances such as when dancing or at other social events. Thus their reason for using the prosthesis was mainly cosmetic. These patients found the PTB-suction prosthesis satisfactory but were used to the ordinary PTB model and in these cases the confidence in its strap suspension made the latter "more practical in daily life". The lack of a visible suspension in the suction model thus proved to underlie a sense of insecurity. In some cases the socket was even constructed so that a strap could be put on, at the request of the patient "in case something should happen".

Among the 20 patients classified as *not adaptable* to the PTB-suction prosthesis there were 5 with a stump shorter than 12.5 cm. Most of these 5 patients were only able to wear the PTB-suction prosthesis for a few hours at a time and when walking cautiously. The suction properties are clearly inadequate for stumps of this size.

Other reasons for non-adaptability were mental and personality derangements, e.g. alcoholism (2 patients), drug addiction (one patient) and lack of co-operation for mental reasons (2 patients). Such patients often neglect their stumps and do not take sufficient care when putting on the prosthesis to make it work properly.

Table IB. *Data for patients not adaptable to the PTB-suction prosthesis*

Name	Participation in earlier studies Ref. (1) Ref. (2) Ref. (3) Ref. (4)	Age	Occupation[a]	Sex	Reason for amputation[b]	Stump length (cm)	Stump periphery (cm)	Type of scar on stump end[c]	Location of scar on stump end[d]	Fibula[e]
J. J.	1 3	36	A	♀	T	5	–	Sm	A	E
G. T.	3	32	A	♀	T	12	(28.5)	Sm	M	E
S. A.	3	50	Se		T	(19.5)	(31.5)	La	M	E
N. W.	1 3	40	H		T	10	–	La	M	S
A. B.		42	A		T	8.5	–	Sm	D	S
L. L.	2 3 4	51	H		T	(15)	(26)	Sm	M	–
J. E. P.	3 4	55	H		T	17	25	Sm	M	S
F. M.		50	A		T	(22)	(27.5)	La	M	S
H. W.		73	Se		K	19	27	Sm	M	S
H. P.		30	S		T	13.2	27.5	La	D	E
O. H.		52	S		T	17.5	26.5	Sm	M	S
A. W.		52	A		T	(14)	(22)	Sm	M	–
J. B.	4	38	A		V	13	24	Sm	M	S
M. N.	2	67	Se	♀	O	25	26	Sm	D	S
H. B.	2	59	Se		T	22	25	Sm	M	S
V. N.		59	Se		Db	16.5	28	La	M	S
S.-O. O.		63	A		T	11.5	(27)	Sm	M	S
B. P.		42	A		T	(18)	(33)	Sm	M	S
S. L.		24	A	♀	T	13	29	La	D	S
R. K.		29	A	♀	C	14	23	Sm	M	–
						$M=15.29$ S.E.$=1.77$ $n=15$ (Figures in parentheses, see table IV)	$M=26.10$ S.E.$=0.59$ $n=10$			

[a] H=Arduous labour. A=Active. Se=Sedentary.
[b] T=Trauma. Tu=Tumour. Db=Diabetes. C=Congenital defect. V=Vascular disease. O=Osteomyelitis.
[c] Sm=Smooth scar surface. La=Laciniated scar surface.
[d] M=On the tibial end. D=Dorsal. V=Ventral. L=Lateral.

Five patients had stumps with extremely prominent bony parts, making the suction ineffective.

The remaining 5 patients gave up using the PTB-suction prosthesis because they had little or no problem with their earlier model and thus saw no reason to change to another prosthetic system. Actually this group of patients could have been put under the heading adaptable to the PTB-suction prosthesis, but were excluded as they stopped using the prosthesis after the 2-month trial and their opinions were therefore uncertain. The suction properties were mostly acceptable, however.

Clinical properties of the stump

Twelve patients developed *skin lesions* when wearing the ordinary PTB prosthesis noted that these recovered when the PTB-suction prosthesis was worn. In 7 of them the skin lesions were graded + (occasional lesions) and in 5, ++ (skin lesions almost perpetually). All 12 patients subsequently did not become wearer of the PTB-suction prosthesis. All of the 7 patients with grade + lesions, continued to use this prosthesis, however. Among the 5 patients with grade ++ lesions, 3 became very well adapted to the PTB-suction prosthesis and continued to use it. The other 2 patients were unable to use this model as both had extremely short stumps —one 8.5 cm and the other 11.5 cm. Both patients tried the prosthesis for some months. When starting the trial one of them had a sore on the end of the stump and the other had severe stump eczema. They managed to use the prosthesis although the suction only lasted a few hours at a time. In spite of this the skin lesions improved. In due time the sore healed and the eczema became much less irritating. These 2 patients regretted that they were unable to use the PTB-suction prosthesis more constantly.

In fact all patients who were unable to wear

Skin lesion graded[f]	Healing of skin lesions using PTB-suction prosthesis	Sensory distur-bances	Soft tissue below skeletal end[f]	Adaptability to PTB-prosthesis/ Conventional prosthesis[f]	Interval (years) between amputation and trial of PTB-suction prosthesis	Lack of cooperation (Lc) or Addiction (Ad)	Bony and slender stumps (B)
–	–	–	++	–/+	14	–	
–	–	–	+	+/–	9	–	
–	–	–	++	+/O	9	–	
–	–	–	0	–/+	10	–	
++	+	+	+	+/+	3	–	
–	–	–	0	+/–	42	–	
–	–	–	++	+/+	43	–	B
++	–	–	++	+/+	19	–	
–	–	–	+	+/	1	–	B
–	–	+	+	+/+	2	Ad	
+	–	–	+	+/	2	Ad	
++	–	–	++	+/+	23	–	
–	–	–	0	–	<1	–	B
–	–	–	0	+/–	43	Lc	
–	–	–	0	O/	47	–	B
+	–	–	0	+/	2	Lc	
++	+	+	0	+/	17	–	
–	–	–	++	+/–	8	–	
+	–	–	0	+/	1	–	B
–	–	–	+	O/O	23	Ad	

[e] –=Absent. S=Shortened. E=Same length as tibia.
[f] See text under Patients and Methods.

the ordinary PTB prosthesis because of a skin lesion and who then tried the PTB-suction model, noticed healing while using the new prosthesis.

The *lengths of the stumps* varied between 5 and 25 cm. Seven stumps measured less than 12.5 cm. Two of these patients were nevertheless able to use the PTB-suction prosthesis. They were a child of about 2 years (stump length 8 cm (6)) and a very slender, short elderly woman (stump length 11.5 cm).

The *stump circumference* varied considerably. Extremely slender stumps with prominent skeletal parts were found to be less suited to the PTB-suction prosthesis, however. The relation between stump circumference and adaptability was studied statistically significant by *t*-testing. This showed that patients who were not adaptable to the PTB-suction prosthesis had, on average, a smaller circumference than those who were adaptable (Table IV).

The *amount of soft tissue* distal to the bony end of the stump varied between 0 and 7 cm. A relation between this amount of soft tissue and adaptability to the PTB-suction prosthesis was also shown (Table V). Patients adaptable to this prosthesis thus had more soft tissue distal to the bony end of the stump. Further 5 of the 6 patients with a large excess of soft tissue below the skeletal end (>3 cm) had had considerable difficulty in using the ordinary PTB-prosthesis.

DISCUSSION

Technical comments on the prosthesis

An optimal prosthesis suspension should counteract movements of the skeletal parts of the stump in the socket as well as movements of the soft stump tissues in relation to the socket wall. At the same time the distribution of the load on weight

Table II. *Reason for amputation*

	No. of patients	Adaptable to PTB-suction prosthesis
Trauma	29	14
Diabetes	3	2
Vascular disease (various)	4	2
Congenital defect	6	5
Tumour	1	1
Osteomyelitis	3	2
Total	46	26

bearing and during the swing phase should be appropriately balanced over the stump (7, 8, 9). To meet this concept the PTB-suction prosthesis is individually constructed according to methods worked out at the Een & Holmgren Orthopaedic Workshop. It will be described in a report as a technical manual which is in preparation (10, 11). The following demands on the prosthesis are especially important:

1) the shape of the socket must correspond to the shape of the individual stump with the soft tissue pre-stretched distally,

2) the fixation in the socket must depend on suction, adhesion and friction,

3) compression of the soft tissue must be strictly minimized.

The necessary compression should, however, have a gradient with the lowest pressure between the skin and the socket wall distally and a continuous pressure increase towards the brim of the socket.

Table III. *Length of the stump bone related to adaptation to PTB-suction prosthesis*

Skeletal length of stump (cm)	Adaptable to PTB-suction prosthesis		Not adaptable to PTB-suction prosthesis		Total
	Men	Women	Men	Women	
0– 4					
4– 8				1	1
8–12	1	1	3	1	6
12–16	6	4	4	2	16
16–20	10	2	6		18
20–24	2	1	2		5
24–28				1	1
Total	19	8	15	5	
	27		20		47

Table IV. *Adaptability to PTB-suction prosthesis in relation to the circumference of the stump*

	Adaptable to the PTB-suction prosthesis	Not adaptable to PTB-suction prosthesis[a]
Circumference (measured 5 cm below tibial tuberosity)	$M=28.90$ S.E.=0.73 $n=26$	$M=26.10$ S.E.=0.59 $n=10$

$t_{34df}=3.06$, $(0.001<P<0.01)$.

[a] n denotes number of legs. All stumps shorter than 12.5 cm are excluded. Patients who stopped using the PTB-suction prosthesis before "giving it a fair trial" are also excluded.

For the PTB-suction prosthesis to function satisfactorily it is important to emphasize this latter point. Negligence here will jeopardize the circulation in the stump (8). The plaster casting of the stump is therefore of fundamental importance (9, 10). The plaster cast must be modelled in a downward direction, so that the soft tissue will accumulate distally in readiness to retract (Fig. 2) (11). This readiness for retraction is the central issue. By this means the distal soft tissue of the stump functions as its own valve which closes towards the brim of the socket, and the gradient compression of the soft tissue from the distal end towards the brim is created. The closely attached socket gives the patient a feeling that the prosthesis is more "like a real leg". This is often expressed. The muscular activity pattern with the PTB-suction prosthesis may also contribute to this feeling (4).

The re-designing of the PTB-suction prosthesis to give it a detachable semirigid inner socket has af-

Table V. *Adaptability to PTB-suction prosthesis in relation to amount of soft tissue below the bony end of the stump*

	Amount of soft tissue (see text)			
	0	+	++	Total
Adaptable to PTB-suction prosthesis	2	4	21	27
Not adaptable to PTB-suction prosthesis[a]	5	4	1	10
Total	7	8	22	37

χ^2, (2 df)=9.19, $(0.01<P<0.05)$.

[a] n denotes number of legs. All stumps shorter than 12.5 cm are excluded. Patients who stopped using the PTB-suction prosthesis before "giving it a fair trial" are also excluded.

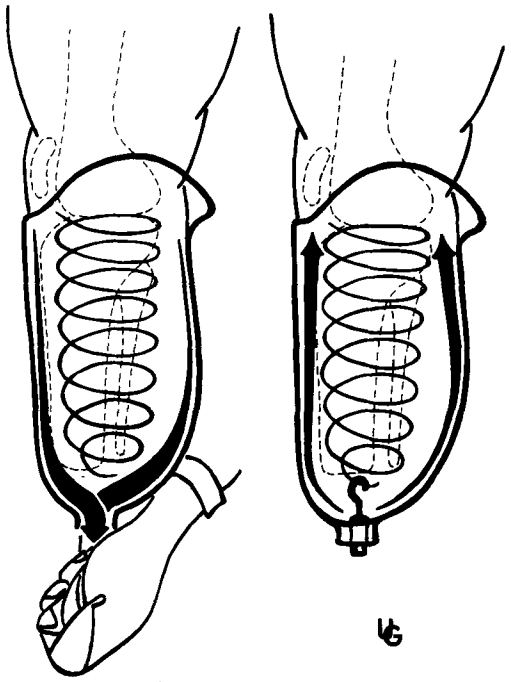

Fig. 2. The figure depicts the accumulated tissue forces at the bottom of the socket when the stockinette is pulled through. The coiled spring represents the total pull down force and the arrows illustrate the main forces in the tissue. The alteration of the direction of the tissue forces after application of the valve is seen. This alteration is a result of the pre-stretching of the soft tissues with the stockinette. The hook of the distal end illustrates the fact that the pre-stretched soft tissues are held in place in the socket in spite of the changed tissue forces.

forded considerable advantages. Most patients have considered that the new model is easier to put on and take off. The softer brim of the socket has eased the problems in the hollow of the knee in extreme flexion. Further, there is less tendency to lose suction under extreme combinations of load and knee flexion (2). This is attributed to the compliance of the semirigid socket wall which reduces the effects of unpredictable forces in any part of the socket. Apart from the convenience in putting on and taking off the prosthesis, the detachability of the socket also comprises a safety precaution in emergency situation such as somersaulting when skiing or cycling. This softer socket thus means that the prosthesis more closely fulfils the three given prerequisites for prosthetic suspension.

Some patients, however, find the rigid, non-detachable socket preferable and this prosthesis should therefore not be forgotten as an alternative.

On account of the special design of the PTB-suction prosthesis with the detachable semirigid inner socket it has been suggested that this prosthesis should have a special name. The name Semirigid Insert Suction Socket PTB-prosthesis (abbreviated SISS-PTB prosthesis) has been coined.

CLINICAL FINDINGS CONCERNING THE STUMPS

Contact sores

In clinical practice the tendency to develope skin lesions with an ordinary PTB prosthesis, and its piston action, are well known (12, 13). This tendency is most pronounced in physically very active persons and in amputation stumps with: (i) sensory disturbances, (ii) excess of soft tissue distally, (iii) frail scar tissue, or (iv) eczema.

The PTB-suction prosthesis is constructed according to the requirements outlined above under Technical comments, specifically to avoid the development of contact sores on stumps prone to skin disorders but also to immobilize already damaged or eczematous skin in order to promote healing and to avoid situations in which the patient is unable to walk with his prosthesis. The effect of the PTB-suction prosthesis on already developed lesions is worthy of note. Thus contact sores—even lingering ones, which occurred with the ordinary PTB prosthesis—healed after the patient had changed to a PTB-suction prosthesis. The sores usually disappeared in a few weeks. This situation was noted in 12 patients.

We therefore consider a PTB-suction prosthesis a treatment method as well as an alternative prosthesis for patients with recurrent contact sores and for those with frail skin, sensory disturbances, or eczema on the amputation stump.

The well known problem of folliculitis in the groin region occurring in patients with the above knee suction prosthesis has an analogue with both the ordinary PTB and the PTB-suction prosthesis. With the PTB prostheses this folliculitis occurs in the hollow of the knee and the mechanism is obvious. As the pulled down stump is fixed, the soft tissue is caught over the edge of the socket opening on flexion, causing repeated irritation.

In the early years after the introduction of the PTB-suction prosthesis this was a minor problem, i.e. the patients never had to stop walking with the prosthesis for this reason, but as the years have passed, a few patients have had considerable trou-

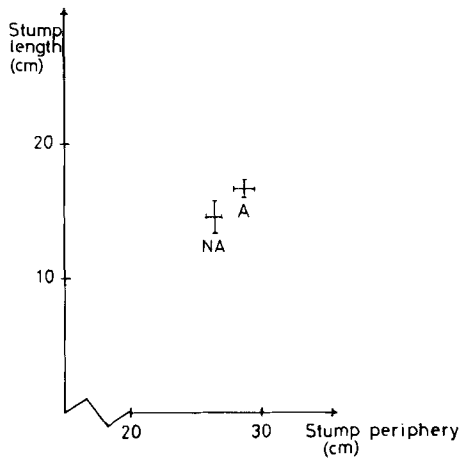

Fig. 3. The two stump characteristics, length of stump and amount of soft tissue, related to adaptability to PTB-suction prosthesis. Patients not adaptable to the prosthesis (NA) have a mean stump length of 15.29 (S.E. 1.77, $n=15$) and a mean stump periphery (5 cm below the tibial tuberosity) of 26.10 (S.E. 0.59, $n=10$). Patients adaptable to the prosthesis (A) have a mean stump length of 16.19 (S.E. 0.56, $n=26$) and a mean stump periphery of 28.90 (S.E. 0.73, $n=26$). The values for both variables, stump length and stump periphery, were thus lower for NA than for A. See text for further details.

ble with this irritative condition. The semirigid insert socket has helped to some extent but the problem still exists.

Stump characteristics in relation to adaptability to PTB-suction prosthesis

Length of stump. One of the first clinical observations was that patients with stumps shorter than 12.5 cm were usually unable to use the PTB-suction prosthesis (1). This has a natural explanation. Thus the skin area of a stump shorter than 12.5 cm is generally too small to establish an adequate suction effect when the centrifugal forces acting on the pendulating prosthesis increase in the swing phase of the gait. For the small child the fitting with a PTB-suction socket prosthesis seems to give excellent control and suspension of the prosthetic aid despite the fact that the stump is much shorter than 12.5 cm (6).

Amount of soft tissue. The amount of soft tissue around and on the distal part of the amputation stump has a complex relation to the adaptability to the PTB-suction prosthesis. It is obvious that patients with slender stumps having a prominent bony end and little subcutaneous fat tissue have difficulty in using the PTB-suction prosthesis. The circumference of the stump also has a statistically significant relation to adaptability. This relation appears to depend upon the amount of subcutaneous tissue. However, in the individual case the amount of subcutaneous tissue is difficult to estimate objectively in a partly destroyed area of the body such as an amputation stump. This is true even when the patient is clearly seen to have a very large or a very small amount.

The amount of soft tissue distal to the bony end of the stump also has a statistically significant relation to the adaptability to a PTB-suction prosthesis. Moreover patients with a very large amount of such tissue have difficulty in using the ordinary PTB-prosthesis. Such patients have nevertheless proved to be among the most satisfied wearers of the PTB-suction prosthesis.

The reason why an amputation stump with an excess of soft tissue is easier to adapt to the PTB-suction prosthesis is evident from the practical point of view. A stump with a large amount of soft tissue (i.e. subcutaneous fat) has a movable and mechanically inert layer that readily adapts itself to the minor unevennesses in the fit of the socket and makes them acceptable (14).

It is obvious, however, that when considering the adaptability to the PTB-suction prosthesis, both the length of the stump and the amount of soft tissue must be taken into account. These two characteristics may be expressed as the variables 'surface area' (volume) and 'elasticity' of the stump. If the stump is not long enough there will be an insufficient area (volume) to establish adequate suction. If the stump lacks soft tissue (subcutaneous fat)—to be drawn down in the putting-on procedure, there is insufficient compliance to establish a gradient pressure. These relations are illustrated in Fig. 3. The patients who are not adaptable to the suction prosthesis (NA) show clearly lower average values of stump length and stump circumference (measured 5 cm below the tibial tuberosity) than the adaptable patients (A). These two variables must thus be considered in combination when a patient's ability to wear the PTB-suction prosthesis is being judged. A stump which is positive in only one of these two respects will most probably be unsuitable for a suction prosthesis. In our study of the pressure variations in the PTB-suction socket both stump length and stump perimeter were found to have a direct influence on the stump socket intercavity

pressure together, as also did the taper ratio between maximum circumference at the top (proximal end) of the stump and the minimum circumference at the bottom (distal end) (2). The function of this prosthetic suspension is almost entirely dependent upon the stump socket intercavity pressure.

Volume measurements of the soft tissue, especially from soft tissue X-ray, with stereo techniques have been considered lately and might be of value in the future (15, 16). The combined measurements of stump length and stump circumference have been regarded as a sufficiently adequate description of the stump volume for the present study.

Social and environmental characteristics in relation to adaptability to PTB-suction prosthesis

The adjustment to a prosthesis is a complex process into which many kinds of variables enter (17). Social and personality factors play an important part in this adjustment. Previous adaptability to another prosthesis is naturally of significance when a patient tries to change to a new prosthetic model. However good a prosthesis is technically, these environmental factors still need consideration. In our series of patients we had three main groups of amputees in whom such factors were decisive for their choice of prosthesis: 1) patients with mental and personality derangements, 2) patients who had previously been well adapted to another prosthesis but had begun to have problems, and 3) patients who were embarrassed by their disability and wanted to conceal it.

The procedure of putting on the PTB-suction prosthesis has some practical disadvantages compared with the simplicity of the ordinary PTB prosthesis. Putting on the suction model requires concentration and carefulness. Patients with mental and personality derangements such as alcoholism, drug addiction or senility often neglect their stumps and do not put on the PTB-suction prosthesis with sufficient care for it to work properly. Such patients should obviously be left with a technically more simple prosthetic aid (9).

Patients in whom problems have developed in a prosthesis which was previously satisfactory may imagine an insuperable situation and will need strong motivation and much psychological encouragement when trying out a new prosthetic aid. It often takes several months to adjust these patients to the new model, with many new plaster casts and new sockets in the meantime.

A highly frequent—though seldom the sole—reason for changing from the ordinary PTB prosthesis to the PTB-suction model, despite its construction for the avoidance of skin lesions, is the cosmetic aspect. The smooth margin between the prosthesis and the rest of the leg gives a natural appearance to the knee region which has been very much appreciated especially by the female amputees, as they have been able to wear skirts without revealing their disability.

General clinical observations concerning the amputation stump

Observations concerning details such as the position or general appearance of the amputation scar and the length of the fibula in relation to the tibia provided no further information beyond what was already known for the ordinary PTB-prosthesis.

Greatly wrinkled scars have given rise to problems in both prostheses, because of the skin-to-skin maceration. The position of the scar—which varied considerably in our series of patients—has otherwise no great influence on the use of the PTB-suction prosthesis. Nor has the length of the fibula proved to have any relation to the use of this model. This is probably more a matter of the amount of soft tissue—as discussed above. Four patients whose amputation was performed for vascular reasons—2 patients with purely vascular disease and 2 with diabetes—adapted to the PTB-suction prosthesis without any ischemic stump problems. Three of the patients had had such problems with the ordinary PTB prosthesis, with consequent sores and blisters. Further, one patient amputated in connection with osteomyelitis 4 years earlier, had suffered intermittent claudication symptoms from the amputated leg just before using the PTB-suction prosthesis. Arterial stenosis was demonstrated angiographically. These symptoms were alleviated by the use of PTB-suction prosthesis.[1]

CONCLUSIONS

The PTB-suction prosthesis was introduced for those wearers of the ordinary PTB prosthesis who often suffered contact sores and skin irritation. It is shown in this clinical presentation that in such cases

[1] Similar effects on intermittent claudication when using the PTB-suction prosthesis have been reported from the Stockholm region.

the skin lesions generally disappear when using the PTB-suction prosthesis. There are still some groups of patients who are left unsatisfied, however, as not all below-knee amputees are able to use this suction model. When the stump is too short the prosthesis is a physical impossibility, and with a too-slender stump with a prominent bony end the problem for the prosthetist in fitting the socket is insuperable. The PTB-suction prosthesis is, however, very practicable for stumps longer than 12.5 cm and with a reasonable amount of subcutaneous tissue. If these two criteria are fulfilled this prosthesis is a good method of treatment as well as an alternative for stumps with areas of sensory disturbance, frail skin, a chronic tendency to contact sores of eczema, and/or ischemic problems. The PTB-suction prosthesis is also cosmetically favourable, and has been particularly appreciated by the female amputees for that reason.

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