Proceedings of the Eighth International Symposium on ECHE, 1984, Dubrovnik

OBJECTIVITY SEARCH PROCESS FOR LOWER LIMB PROSTHETIC ALIGNMENT

Kovalko N.T., Lysenko N.A., Drachik J.N., Zarudny S.

Abstract

Individual prosthetic alignment is a very important technological step that affects greatly the prosthetics quality.
Taking into account the fact that the prosthetic alignment must be determined not only by mutual positions of the parts and joint of the prosthesis in relation to the locomotive system but it must also take into consideration the forces affecting the prosthesis, our institute developed a special device (DDPA). This device made it possible to locate on the horizontal plane the projection shift of resultant forces affecting the prosthesis in sagittal and frontal planes. The device consists of a load distribution measuring instrument, a tensiometer-amplifier and XY-recorder. The latter draws a closed curve, showing the forces resultant projection shift on horizontal plane during patient's walk. Combined clinical and biomechanical investigation of 57 patients fitted with unified lower extremity prostheses was carried out with the purpose of finding the curve objective parameters. As a result of investigation all patients were devided into two groups. The first group included patients with optimum prosthesis alignment (66%). The second group included patients with unsatisfactory prosthesis alignment (34%). The forces resultant projection trajectory recorded by the DDPA was characterized by stable forms and sizes for the first group of patients. For the second group the forces resultant curve differed considerably in shape and size from the curve recorded for the first group of patients. Detailed clinical data comparison with the curve features permitted to discover the dependence between the curve and certain prosthesis alignment parameters. This fact permitted us to use the DDPA for the objective assessment of the prosthesis alignment quality and for its proper necessary correction.

Introduction

One of the basic technological steps that influences the quality of prosthetic fitting is the individual alignment determining. The alignment chosen initally in the process of prosthesis assembling very often requires certain correction in use. But the design of the mass-produced prostheses makes it impossible to realize. For this purpose the Ukrainian Prosthetic Institute developed and put into production unified above-knee and below-knee modular prostheses that allow us to change the prosthetic alignment quickly and easily by means of special linking and adjustable devices.

Due to the fact that the prosthetic alignment must be determined not only by mutual location of joints and parts of the prosthesis when they are assembled concerning the locomotive system but must also take into account forces affecting the prosthesis in use, a group of authors developed a special device for determining the prosthetic alignment (DDPA) which gives an opportunity to determine and locate the projection place for resultant forces that affect the prosthesis in sagittal and frontal planes.

The device is made up of a load distribution measuring instrument, a tensiometer-amplifier, XY-recorder. The latter draws a closed curve that shows the resultant forces projection on the horisontal plane.

57 patients with unilateral below-knee and above-knee amputation were examined. There were 52 men and 5 women from 20 to 50 years among the disabled patients. 20 patients had shin defects in the middle and 16 patients in the upper third, 12 and 9 patients correspondingly had hip defects. These disabled patients were fitted with unified prostheses for investigation. The sockets were thoroughly fitted and only after that prostheses were assembled a prosthetic alignment measuring instrument. Parameters proposed by the Central Prosthetic Institute were used as original data. For the disabled patients with shin defects Unified prosthesis were designed by the following parameters (Table I)

Table I

Below-Knee Prosthetic Alignment Parameters

Parameters	X_I mm				Y_I mm	α foot	γ	
	2	3	4	5	0	6°	I,5	I,0
Patients	9	I0	9	8	36	36	I7	I9

where:

X_1 -knee joint axis center horizontal shift from the vertical line that passes through the axis center of ankle-foot joint (technological base) in frontal plane

Y_1 -as above in sagittal plane

α -foot turn

γ -ankle-foot axis joint turn outside relative to the limb front plane.

Clinical assessment of the prosthetic alignment showed that these parameters were optimum for 25 from 36 patients. Standing and walking the foot evenly contacted the floor by its distal and lateral surfaces. The disabled patients felt evenly distributed pressure on side surfaces of stumps. Plantar surface in sagittal plane also evenly contacted with bearing surface. The patients felt stability with the prosthesis.

Podographical investigations results (table 2) and trunk side inclinations measurements (table 3) indicated rhythmic gait, movement symmetry of both healthy limbs and artificial limbs.

Table 2

Invalids Podographical Investigation Results with Unified Below-Knee Prostheses

Investigated object	time intervals (%)							rhythmic coefficient
	t_I	t_2	t_3	t_4	t_5	t_6	t_7	
Artificial limb	I3± I,2	5,4± 0,6	29,I± 2,6	II,2± I,2	5,4± I,I	35,9± I,9	64,I± 2,3	0,98
Healthy limb	9,I± I,4	7,5± 0,7	32,0± 3,8	II,3± I,4	5,9± 0,9	34,2± 3,4	65,8± 3,4	
Normal	7,7± I,3	7,2± 0,6	28,2± 7,0	I5,0± 3,I	5,3± 0,7	36,5± I,5	63,6± 2,6	0,99

Table 3

Side Inclinations Investigation Results during Walking with Below-Knee Prostheses

Trunk side inclinations during walking, degrees			
Prosthesis side	Healthy limb side	Normal	
		right	left
3,5 ± I,0	3,6 ± 0,8	7,0 ± 0,5	6,5 ± 0,5

Graphical description of resultant forces projection shifts that affect the prosthesis in frontal and sagittal planes made it possible to get the closed curve charaterizing this group of patients. (Fig.I).

Alignment assessment clinical data indicated that parameters mentioned above were not optimum for II invalids. These patients felt exceeding pressure on the outside surface of residual limb butt-end that became stronger in the process of walking, consequently the frontal component of a step increased. These invalids' gait was not rhythmic and side inclinations were asymmetric.

The DDPA curves considerably differed from the curves that characterize the gait with optimum alignment parameters of below-knee prostheses. In particualar, considerable reduction in fluctuation range shifts of resultant forces projection relative to the axis Y (Fig.2).

Thorough clinical analysis of unsatisfactory prosthetic alignment results showed that these results were caused by the fact that the outside below-knee stump deviation by 6-11° was not taken into account with this group of patients. Special adjusment device of the unified prosthesis made possible a quick and easy alignment correction in the process of assembling, i.e. socket deviation by the angle, corresponding to the outside stump deviation in frontal plane. These devices led to satisfactory clinical and biomechanical results. Resultant forces projection shifts data, recorded after the correction, indicated the curves similar in size and shape to those of the first group of disabled patients i.e. registered for the prostheses with optimum assembling alignment parameters (Fig.3).

For the patients with AK defects unified prostheses alignment was carried out by the following parameters.

Table 4

Above-Knee Prosthesis Alignment Parameters

Parameters	β°			X_2 mm			Y_2 mm			α_{foot}°
	2,5	2,0	0,5	I7	35	40	4	5	6	6
Patients	4	8	9	I4	4	3	I0	6	5	2I

β°-AK socket inclination angle

X_2- horizontal shift of femoral socket middle cross-section in frontal plane from technological base

Y_2- as above in sagittal plane

Clinical assessment of unified AK prostheses alignment showed that the alignment parameters indicated in table 4, where X_2 was 17 mm(zero alignment) were optimum for 14 patients.

Fig.I. Patient´s B curve. Right shin defect, middle third level. Optimum parameters of prosthesis assembling alignment.

Fig.2. Patient´s P curve. Left shin defect, upper third level. Outside stump deviation 7^{o} was not taken into account in the alignment of the prosthesis.

Fig.3. Patient´s P curve after the correction of the prosthesis alighment that was carried out by socket inclination by 7^{o} in frontal plane.

0- the moment when foot touches surface.

H- the curve during heel contact

T- the curve during toe contact.

Gait investigation by means of electopodography (Table 5) and side inclinations of the trunk indicated rhythmic and smooth gait, movements symmetry for artificial and healthy limbs.

Table 5

Podographical Investigations Results for the Patients with Unified Hip Prostheses

Investigated object	time intervals %							rhythmic coefficient
	t_I	t_2	t_3	t_4	t_5	t_6	t_7	
Prosthesis fitted limb	8,5± I,5	4,9± 0,7	34,8± 3,6	9,0± I,6	5,8± I,5	36,8± 2,8	63,2± 2,6	0,85
Healthy limb	8,8± I,9	4,3± 0,8	45,3± 4,I	II,2± 2,I	6,7± 0,8	25,4± 4,3	74,6± 4,4	

Table 6

Trunk side inclinations investigations results with unified AK prostheses

Trunk side inclinations during patient's walk. Degrees	
Prosthesis side	Healthy limb side
6 ± 0,82	5 ± 0,73

Graphical recording of forces resultant projection shift was carried out for 12 patients with above-knee prostheses assembled by zero-alignment. The curves received were similar in shape and size with those that were indicated for the patients with optimum alignment parameters of below-knee prostheses (Fig.4).

For 7 patients whose above-knee prostheses alignment parameters were 35-40mm, clinical observations discovered higher pressure in perineum, frontal step component reduction (step width) at the prosthesis side and gait difficulties. Podogram investigation results show arhythmic gait (avarage rhythmic coefficient is 0,78) asynchronous movements of artificial and healthy limbs.

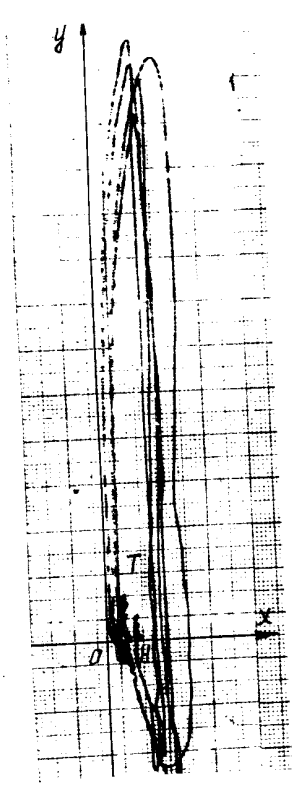

Fig.4

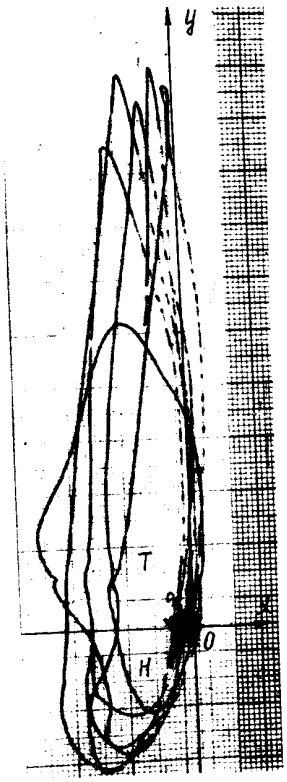

Fig.5

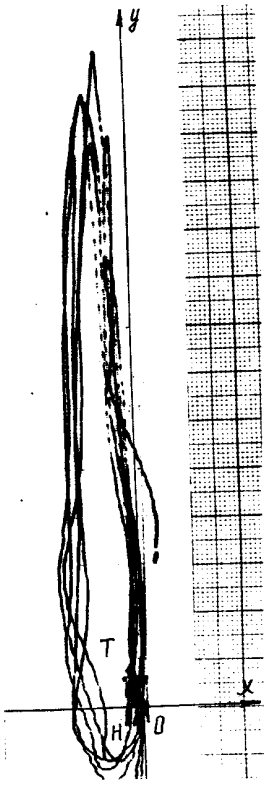

Fig.6

Diagrams describing forces resultant projection shift for above-knee prosthesis in sagittal and frontal planes.

Fig.4. Patient´s N. curve. Left hip defect, upper third level. Optimum prosthesis alignment parameters (zero alignment).

Fig.5. Patient´s P. curve. Right above-knee defect, upper third level. With diverging alignment of the prosthesis (X_2=40mm).

Fig.6. Patient´s P. curve after alignment correction by means of X_2 parameter reduction from 4- to 17 mm.

Side inclinations of the trunk to the prosthesis side were lower to the side of the healthy limb.

Graphic recording of resultant forces projection shift shows the curves (Fig.5), that differed considerably, as for their shape and range, from the curves recorded during gait with the optimum alignment parameters prostheses. Resultant projection deviation range shifts increased considerably in frontal plane. Operative correction of unified above-knee prostheses alignment by means of adjusting devices resulted in parameters X_2 reduction from 35-40 mm to 17 mm. The curves obtained for all 7 patients were characteristic for the patients with optimum alignment parameters prostheses (Fig.6)

It should be noted that in two cases with satisfactory clinical assessment of BK prostheses alignment and with satisfactory podogram results of gait investigation, recording of forces resultant projection shift did not correspond to the curves, obtained during walk with the optimum prosthesis alignment parameters. After the correction of the alignment by increasing parameters - sagittal plane socket inclination from $0,5^{\circ}$ to 2° - the curves became similar to the Fig.4. curves in shape and size. At the same time patients indicated that their gait became easier.

Our investigation also discovered that the deviation range of resultant forces projection shift relative to the X axis directly depends on the double step length. The latter depending on the speed of the walk, the most important thing our data for the curve characteristics in sagittal plane being the ((toe) : H (hed) length relation. Normally this relation is 3,5:I. When prostheses are assembled incorrectly, the length of every curve section (T or H) in sagittal plane may vary. When the heel support is not enough, the H section of the curve will be decreased, when the toe support is not enough, it will be increased. In these cases the alignment adjusment is carried out by means of the shin tube inclinations. Forces resultant projection shifts in sagittal plane normally range from 90 to 160 mm, average $119 \pm 22,5$; frontal from 8 to 16 mm, middle $-12 \pm 2,1$mm.

Thus, by shape and size of the curve, recorded by the DDPA one may evaluate the AK and BK prostheses alignment and if necessary one can make its proper corrections.