LAPOC SYSTEM LEG

The Development of Modular Endoskeletal
Lower Limb Prostheses Specially Designed
for Japanese Life Style

THE LABOR ACCIDENT PROSTHETICS
& ORTHOTICS CENTER

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1. Introduction

The Labor Accident Prosthetics & Orthotics Center in Nagoya, Japan was settled at 1969 by the fund of Labor Ministry. One of main objective of this Center was to develop a new prosthetic system of practical level, not sophisticated, because there were only limited components and techniques to fabricate modern prostheses at that time. It seemed to us that development of the system in endoskeletal modular design was preferable due to following reasons.

- 1) The concept of this construction was new and charming.
- 2) The techniques and components of wood prostheses were not popular at that time.
- 3) This type of construction was seemed profitable in designing prostheses to fulfill Japanese special requirements such as sitting on TATAMI mattress.

At first, we have developed a pylon for below knee amputation at 1972. This adjustable leg have been used over four hundred amputees mainly for post surgical temporally use. And at the beginning of 1977, we have developed a protomodel of prosthetic system for lower extremity amputations. The special features of this system are 1) to exclude wood material from the construction members 2) to have built-in alignment adjustable mechanism of tilt and slide type which is also act as thigh length adjustment spacers 3) to have axial rotation module of knee and shank. The system is composed from nine fundamental modules. The basic material of hardwares are aluminum alloy except joint axis, screws and socket base metal. The average weight of finished prostheses are 2.9 kg. in A/K and 1.6 kg. in B/K prostheses including plastic sockets. This system was sent to the market at Sept. 1978 and at the end of April 1980, over one thousand assemblies were already used by Japanese amputees as well as those of South East Asia.

2. Construction

2-1 Built-in alignment mechanism

The SOCKET BASE which is attached to the bottom of the socket during fabrication procedure has a bolt to connect holding module named SOCKET BASE HOLDER and allows tilting adjustment within a range of sixteen degrees for all directions as well as rotation around long axis of the leg. In above knee prostheses, SOCKET BASE HOLDER and knee are coupled by a module named CROSS SLIDER which allows A-P and M-L displacement within a range of ten mm separately.

The system has another mechanism for tilting thigh or shank tube named ALIGNMENT SLEEVES. These sleeves are inserted between tube and tube holder. They are fixed simply by tightening the screw of the holder without fear of loosening.

Tilting adjustment is easily performed by rotating the sleeves simultaneously to proposed directions. Adjustment range is twenty four degrees for all directions. This mechanism is simpler and less expensive compared to the WEDGE DISKS of similar principle. In this LAPOC system, the device is adopted at the distal end of thigh and shank tubes to achieve tilt and tilt alignment as well as heel height adjustment.

Fig. 1 ALIGNMENT SLEEVES

2-2 Length adjustment of the thigh

Most of modular endoskeletal limbs in advance are designed that length adjustment of the thigh will be performed by cutting the wood block when applied for long and medium stump cases. However, considering recent tendency in amputation surgery of leaving stump as long as possible and average short length of Japanese lower extremity, the ratio of amputees who need module for long stump are possibly higher than in Western countries. Therefore, to adopt series of spacers between stump and knee module instead of wood is preferable from view point of easier fabrication and quick service. In this system, we already have the module CROSS SLIDER for horizontal displacement and quick disconnection, it is not difficult to make them higher to act as a spacer for adjustment of thigh length. And now, the system has a series of CROSS SLIDER from 0 mm to 50 mm height without much increase of weight and cost. They are

Fig. 2 MODULES OF LAPOC SYSTEM LEG

different in length by 10 mm each other. The prosthetist simply select one of them according to the left space between SOCKET BASE HOLDER and knee module after fabrication of socket without any consideration of thigh length. In addition, it became easy to add axial rotation unit of knee and shank (TURN TABLE) between socket and knee by the favour of this construction. The device is optionally combined with CROSS SLIDER and act as a member in adjustment of length and horizontal displacement. With combination of two or three of above knee modules, from the mininum (55 mm) to the maximum (145 mm) of left space between socket base and knee joint axis is able to connect within a error of 5 mm allowing full alignment range.

2-3 Special function modules for the Japanese patient

As shown in Table 1, the Japanese patients have three major requirements which might be special for Western people. Those requirements are more intensive when patient wish to visit someone in his house or, of course, in case of female amputee.

With combination of TURN TABLE and full flexion knee, this prostheses allows easy access to the shoe of prosthetic side as well as sitting on a TATAMI mattress in two different styles. To fulfill the third requirement of Table 1, switching the height of instep bumper is adopted in sacrifice of normal heel bumper action at bear foot walking.

REQUIREMENT	ANSWER
1 Put on & take off SHOES easily	* add TURN TABLE mechanism above knee joint with full flexion knee
2 Sitting on the floor (Knee flexed over 140)	
3 To walk easily without SHOES	* flat heel foot and shoes * add another joit with locking mechanism above ankle axis * adjust height of instep bumper

Table 1. Requirements of Japanese patients

Fig. 3 CROSS LEGGED SITTING

Fig. 4 BENT KNEE SITTING

2-4 Knee modules and ankle foot assembly

Three types of knee modules are available from functional view point. They are constant friction knee, safety knee of weight yielding type and manual locking knee. From view point of stump length, two types of knee modules are available. The one is for average stump and the other is for extra-long stump only. With adoption of this knee module even through femoral condyle stump can be furnished with full function knee allowing tilting and axial rotation adjustment in the same knee axis level of sound side. These knee modules are all single axis type and allows full flexion. Swing control is attained by combination of constant mechanical friction around knee axis, all concealed in shank tube after assembly. The moulded foot contains core of high durable urethane rubber attached to metal keel and applicable to very long below knee stump including Syme.

3. Physical testing

Physical testing of main modules and assembled prostheses are continuously performed from the beginning of development stage. At present, testing is undergone by specification of ISPO recommendation. Some of the results are shown in Fig 5, 6

Fig. 5 LOAD-DEFLECTION CURVE OF LAPOC FOOT IN CYCLIC LOAD TEST

Fig. 6 LOAD-DEFLECTION CURVE OF LAPOC ANKLE IN CYCLIC LOAD TEST

4. Result of clinical application

The LAPOC limbs have been applied to one hundred and sixty two amputees of TOKAI area (middle Japan) from Autumn 1978 to Spring 1980. The half of them have been interviewd and checked their prostheses by LAPOC members at May 1980.

In the following, analysis of cases, prescription and service will be discussed. In addition, subjectiv evaluation of this prosthetic system by wearers will be introduced which might be a forecast of future share of this type of prostheses in Japan.

4-1 Analysis of cases

Total number of interviewed cases are 77. They are eight HIP, fourtyfour A/K, twentyfive B/K including three bilateral amputees. Twenty percent of them are female, average age is about fourty and 37% are engaged in out door works. Elapsed years after amputation is over eleven in average and two third are lost their limbs due to trauma. Average body weight is under 60 kg. Activity level of cases are shown in Table 2.

4-2 Required time before delivery

Average duration between casting of the stump and delivery of prostheses is about 6.5 weeks. Compared to previons delivery, it is clear that modular limb can't effect in reduction of time to deliver except HIP cases because too much time is spent in socket fabrication and fitting check.

ACTIVITY LEVEL OF CASES

	HIP (8)	A K (44)	B K (25)
10 m. level walking time (a v.)	12.0 sec	11.0 sec	8.3 sec
walk outside with cane assist	25 %	21 %	16 %
can do any type of sports	25 %	34 %	40 %
able to up & down stairs without hand assist	50 %	82 %	80 %
often walk carrying load (3kg)	50 %	39 %	56 %

Table 2

DURATION BETWEEN CASTING & DELIVERY (70, except fresh cases)

Table 3

4-3 Analysis of prescription

Applied number of function modules is shown in Table 3. These modules are selected by doctors, prosthetist and patient himself from functional view point. Safety knee of weight yielding type is applied in 60 % of above knee amputee and special function module is applied over 90 % of cases. Finished weight of the limbs are 3.5 kg. with Canadian hip prostheses, (Hip module of OTTO-BOCK is applied), 3.0 kg. with above knee and 1.6 kg. with below knee prostheses in average.

SPECIFICATION OF DELIVERED LAPOC SYSTEM PROSTHESES

80 LIMBS	HIP (8)	AK (44)	BK (28)
DURATION AFTER DELIVERY (AV)	12.6M	11.8M	12.8M
MANUAL LOCKING KNEE	3	7	
CONSTANT FRICTION KNEE	2	8	
SAFETY KNEE	3	29	
TURN TABLE	8	41	
HEEL HEIGHT ADJUSTABLE ANKLE	8	43	28
FINISHED WEIGHT (AV)	3481g	2930g	1605g

4-4 Maintenance service

Table 4

Ten percent of function modules are repaired or exchanged to new one during average twelve months of time after delivery. Damaged section repaired modules are mainly extension or dorsiflexion stop of plastic material.

4-5 Breakage ratio of foam cover

One piece type of foam cover (morporene) is adopted for above knee prostheses. Average duration before break is 3.7 months and 70 % of them are damaged at anterior part of the knee joint. Only one third of wearers visited prosthetist to repair the broken part and only four amputees exchanged to new one.

DURABILITY OF FOAM COVER
(52 HIP, AK PROSTHESES)

Table 5

4-6 Utilization of special function modules

• RATIO OF BREAKAGE WITHIN 6 MONTHS	9 2 %
• AV. DURATION BEFORE BREAK	3.7 MONTHS
• BROKEN PART	
ANT. PART OF THE KNEE	7 1 %
DISTAL PART OF SHANK	1 3 %
OTHERS	1 6 %
• CAUSES OF BREAKAGE	
STUMBLING	3 0 %
KNEELING	2 3 %
NO SPECIAL MOMENT	4 0 %
OTHERS	7 %
• REPAIRED BY PROSTHETIST	3 3 %
• EXCHANGED	7 %

Axial rotation unit of knee and shank is indispensable to sit on the floor wearing above knee prostheses. Therefore, 96 % of cases are favoured with this new function. Main situations to utilise the module are putting a shoe on prosthetic foot and sitting on the floor cross legged. On the contrary, switching mechanism of instep bumper of the foot is under welcomed by above knee amputees than we expected before. It might be due to difficulty to access

to the foot level and not smooth action of the switching mechanism.

UTILIZATION OF SPECIAL FUNCTION MODULES

• TURN TABLE (axial rotation module of knee and shank)

UTILIZE: 96% 47/49 cases

W H E N	to put on the shoe	to take off the shoe	sitting on the floor		sitting on the chair
	64%	47%	cross legged	others	23%
			64%	32%	

• HEEL HEIGHT ADJUSTABLE ANKLE

UTILIZE when to walk BARE FOOT

HIP + AK 16/39 cases 41% BK 13/16 cases 81%

Table 6

4-7 Acceptance by wearers

Seventy cases have been changed their prostheses from conventional wood one to LAPOC system. They are interviewed concerning to their subjective evaluation of new artificial limb compared to previous one in seven features and ACCEPTANCE RATIO was introduced from their answers. The result shows that better cosmesis and light weight are highly evaluated as well as better and new functions, however, durability and noise are not much improved by this endoskeletal prostheses. Consequently, eighty six percent of them wishes to have this prostheses in next chance of delivery.

(ACCEPTANCE RATIO of 70 cases except fresh amputees)

Table 7

5. Conclusion

Basic philosophy, construction, and results of clinical application of LAPOC modular prostheses is stated in this paper. It is clear that this prostheses is highly evaluated by wearers mainly by the reasons of light weight and new functions which improve their daily life activities. And not by the differences of quick service, strength, or reliability in comparison to former conventional limbs.

It can be concluded that the situation surrounding Japanese modular prostheses is basically different from that of western countries. In Japan, the construction can provide new "attractive function" instead of better cosmesis which only attained by indurable foam cover.

Therefore, if we make more efforts to get high reliability both in hardware and outer shaping without sacrifice of weight and cost, then, those superiorities of modular design such as easier fabrication, quick service, interchangeable functions etc. might be more highly evaluated by prosthetists and prescription doctors.

DO YOU CHOOSE LAPOC PROSTHESES AGAIN?

☐ YES

☒ YES, IF NO EXTRA PAYMENT

☐ NO

☒ OTHERS

APPLIED NUMBERS OF LAPOC SYSTEM LEG

SEPTEMBER 1978 - APRIL 1980

	ABOVE KNEE	BELOW KNEE	TOTAL
DOMESTIC	653	441	1094
OVER SEA	21	28	49
TOTAL	674	469	1143