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Survey of above knee (A/K) prostheses currently used in the Chugoku-Shikoku district of Japan

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Abstract

To determine the extent to which recent advances in biomechanical technology have been implemented and to evaluate these new technologies, 84 unilateral above knee (A/K) amputees and their prostheses were surveyed in the Chugoku-Shikoku district of Japan, especially in regard to the types, sockets and components of A/K prostheses currently in use. Background factors such as age and sex of the A/K amputees and the period after amputation were also surveyed. Of the 84 amputees surveyed, 74 (88.1%) were over 40 years old and 40 (47.6%) were over 60 years old. There were 10 women (11.9%) and 74 men (88.1%). The period after amputation was under 25 years in 58 (69.0%) cases. Regarding the type of A/K prostheses, one-third of the prostheses was of the exoskeletal type and two-thirds were of the endoskeletal type. Although the endoskeletal type is becoming more popular recently, elderly A/K amputees tend to use the exoskeletal type. Thirty-one (36.9%) had plug-fit sockets which are preferable for those who follow the Japanese practice of sitting on the floor, especially for elderly amputees. Thirty-seven (44.0%) had a lock-knee, 27 (73.0%) of which were used by amputees over 60 years old. Seventy-three (86.9%) had a single-axis ankle which is generally considered to be the most stable ankle. Thus, the most common combination of prosthetic components for elderly A/K amputees was the plug-fit socket, lock-knee joint and single-axis ankle.

KEYWORDS: above knee prosthesis, elderly amputees, Japanese life style, advanced biomechanical technology, prosthetic components

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Survey of Above Knee (A/K) Prostheses Currently Used in the Chugoku-Shikoku District of Japan

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To determine the extent to which recent advances in biomechanical technology have been implemented and to evaluate these new technologies, 84 unilateral above knee (A/K) amputees and their prostheses were surveyed in the Chugoku-Shikoku district of Japan, especially in regard to the types, sockets and components of A/K prostheses currently in use. Background factors such as age and sex of the A/K amputees and the period after amputation were also surveyed. Of the 84 amputees surveyed, 74 (88.1%) were over 40 years old and 40 (47.6%) were over 60 years old. There were 10 women (11.9%) and 74 men (88.1%). The period after amputation was under 25 years in 58 (69.0%) cases. Regarding the type of A/K prostheses, one-third of the prostheses was of the exoskeletal type and two-thirds were of the endoskeletal type. Although the endoskeletal type is becoming more popular recently, elderly A/K amputees tend to use the exoskeletal type. Thirty-one (36.9%) had plug-fit sockets which are preferable for those who follow the Japanese practice of sitting on the floor, especially for elderly amputees. Thirty-seven (44.0%) had a lock-knee, 27 (73.0%) of which were used by amputees over 60 years old. Seventy-three (86.9%) had a single-axis ankle which is generally considered to be the most stable ankle. Thus, the most common combination of prosthetic components for elderly A/K amputees was the plug-fit socket, lock-knee joint and single-axis ankle.

Key words: above knee prosthesis, elderly amputees, Japanese life style, advanced biomechanical technology, prosthetic components

Several types of sockets and components for above knee (A/K) prosthesis have been introduced recently. They have contributed the prosthetic function, not only in walking but also in sports activity with advanced technology. Japanese A/K amputees seemed to have benefited from recent advances in biomechanical technology, but few studies have been carried out on A/K prostheses which are currently in use.

To analyze actual needs of A/K amputees in relation to the types of prostheses now available, we conducted a survey in the Chugoku-Shikoku district of Japan with regard to the types, sockets and components of A/K prostheses currently in use.

Patients and Methods

We studied 84 unilateral A/K amputees (right 36, left 48) and their A/K prostheses which were prescribed by us for one year between April 1993 and March 1994. Of the 84 A/K prostheses, 43 were issued at the Rehabilitation Consultation Center for Physically Disabled Persons of Okayama Prefecture, and 41 at limb-fitting clinics affiliated with the Kibikogen Rehabilitation Center for Employment Injuries. Our limb-fitting clinic was held at 20 places in the Chugoku-Shikoku district which has population of about 12 million.

The following aspects were surveyed: 1) age, 2) sex, 3) period after amputation, 4) type of prosthesis (exoskeletal or endoskeletal), 5) sockets, including suspensions, and 6) prosthetic components (knee joints, turntables and ankle-feet).

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Results

The age of amputees ranged from 23 to 82 years old (57.9 ± 14.0, mean ± S.D.). Of the 84 amputees, 74 were men and 10 were women (Fig. 1).

The period after amputation ranged from 7 months to 55.5 years (20.9 ± 14.7) (Fig. 2).

Twenty-nine prostheses were of the exoskeletal type and 55 were of the endoskeletal type.

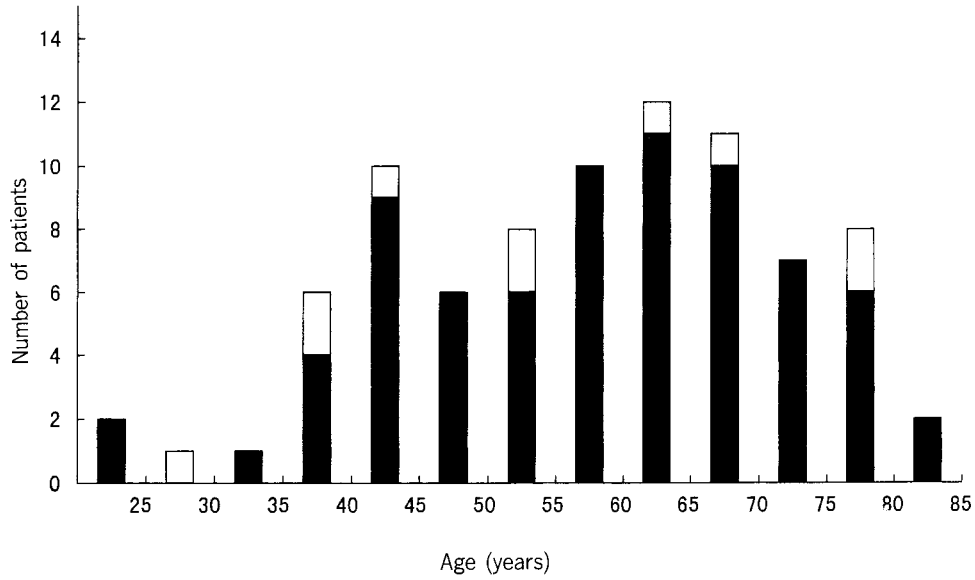

Fig. 1 Age distribution.
n = 84, patients ranged from 23 to 82 years old (57.9 ± 14.0). ■: Male; □: Female

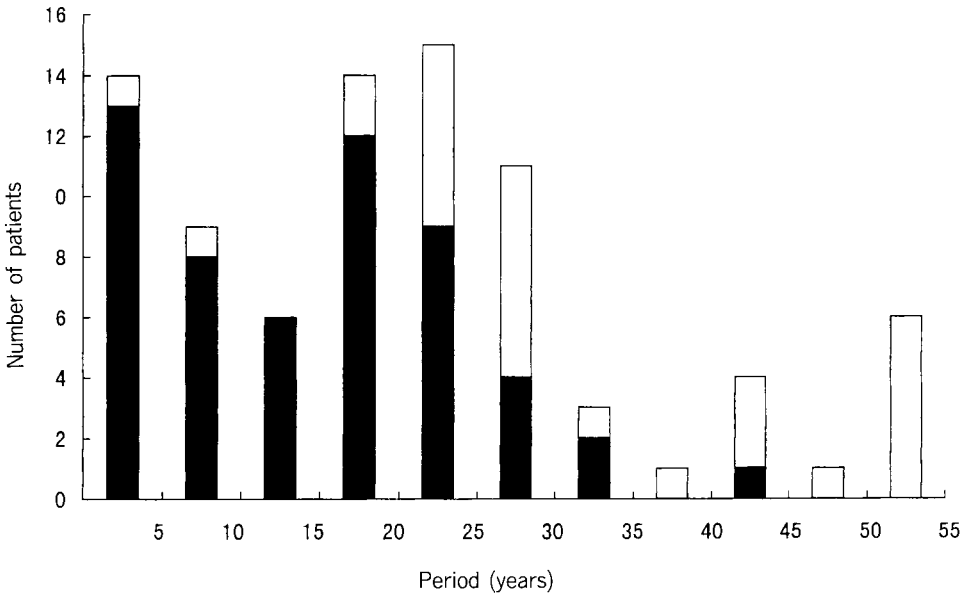

Fig. 2 Period after amputation.
n = 84, period ranged from 7 months to 55.5 years (20.9 ± 14.7). ■: Endoskeletal type; □: Exoskeletal type

Most of the sockets of the exoskeletal prostheses were plug-fit and most sockets of the endoskeletal ones were total-contact. The total-contact sockets were divided into two kinds; the quadrilateral socket and the ischial ramal containment (IRC) socket. The types of prostheses and sockets are shown in Table 1. Of the 53 total-contact sockets, 12 were of the Icelandic-Swedish-New York (ISNY) type. The ISNY type socket consists of two parts: a soft part encasing the stump and a hard part supporting the body weight. Two IRC sockets were of the ISNY type.

All 31 A/K prostheses with plug-fit sockets had suspensions; 10 had shoulder suspension bands, 9 had pelvic bands and 12 had Silesian bandages. Of the 53 A/K prostheses with total-contact sockets, 28 had Silesian bandages.

Of the 55 endoskeletal prostheses, 47 had turntables. Five kinds of turntables were used; 13 LAPOC (M0610 = 7, M0620 = 6), 6 Takasaki (TG2014) and 28 Otto Bock (4R45 = 7, 4R57 = 21).

Two kinds of prosthetic knee joints in exoskeletal prostheses were used; 22 lock-knee joints (Obara 27B-011 = 6, 34B-04 = 1, Keiai KI-BU-B19 = 13, KI-BU-B102 = 1, Otto Bock 3P4 = 1) and 7 single-axis knee joints with constant friction (Obara 34B-01 = 5, Keiai KI-BU-B103 = 2).

Four kinds of prosthetic knee joints were used in endoskeletal prostheses; 15 lock-knee joints (LAPOC M0726 = 7, Takasaki TG1005 = 1, TG1014 = 4, Otto Bock 3R17 = 2, 3R40 = 1), 35 safety knee joints (LAPOC M0730 = 5, M0736 = 3, Takasaki TG1011 = 1, Otto Bock 3R15 = 25, Blatchford 019316 = 1), 4 polycentric knee joints (LAPOC M0750 = 1, Takasaki TG1027 = 1, Otto Bock 3R21 = 1, Hanger U-704B = 1) and one was a microcomputer-controlled knee joint (Intelligent knee, NABCO NI-A110). The Otto Bock products were made in Germany and the Blatchford and Hanger products were made in the UK (Table 2).

Four kinds of prosthetic ankle-feet were observed in exoskeletal prostheses; 21 single-axis ankles (Keiai KI-SG-A28 = 20, KI-SG-M50 = 1), 4 Dollinger feet (Obara 42B-040 = 4), 3 fixed ankles (Obara 42B-030 = 3) and 1 Seattle foot.

Three kinds of prosthetic ankle-feet were used in endoskeletal prostheses; 52 single-axis ankles (LAPOC M1002 = 11, M1030 = 4, M1040 = 2, Otto Bock 2R10 = 30, Hanger U752-B = 5), 1 polycentric ankle (Blatchford 379242), 2 SACH feet (Dynamic foot = 1, Seattle foot = 1) (Table 3).

Because the prosthetic ankle-foot consists of an ankle joint and a foot component, the foot component corresponds to the ankle joint in each endoskeletal prosthesis. The foot components used were as follows; LAPOC M11 for LAPOC ankles, Otto Bock 1H38 for Otto Bock and Hanger ankles, and Blatchford 509153 for Blatchford ankles. The Dynamic foot was made in Germany and the Seattle foot was made in the USA.

Table 1 Prescribed sockets

	Plug-fit	Total-contact		Total
		Quadrilateral	IRC[a]	
Exoskeletal	23	6		29
Endoskeletal	8	45	2	55
Total	31	51	2	84

a: Ischial ramal containment socket

Table 2 Prescribed knee joints

	Lock	Single-axis	Safety	Polycentric	Micon[a]	Total
Exoskeletal	22	7				29
Endoskeletal	15		35	4	1	55
Total	37	7	35	4	1	84

a: Microcomputer controlled knee joint

Table 3 Prescribed ankle-feet

	Single-axis	SACH[a]	Polycentric	Dollinger	Fixed	Total
Exoskeletal	21	1		4	3	29
Endoskeletal	52	2	1			55
Total	73	3	1	4	3	84

a: Solid ankle cushion heel

Discussion

The recent development of the sockets and components of A/K prosthesis is based on advances in biomechanical theory. Kristinssen (1) developed the ISNY type socket in 1983. This inner flexible socket affords excellent fit of the stump, and the outer rigid frame supports the body weight.

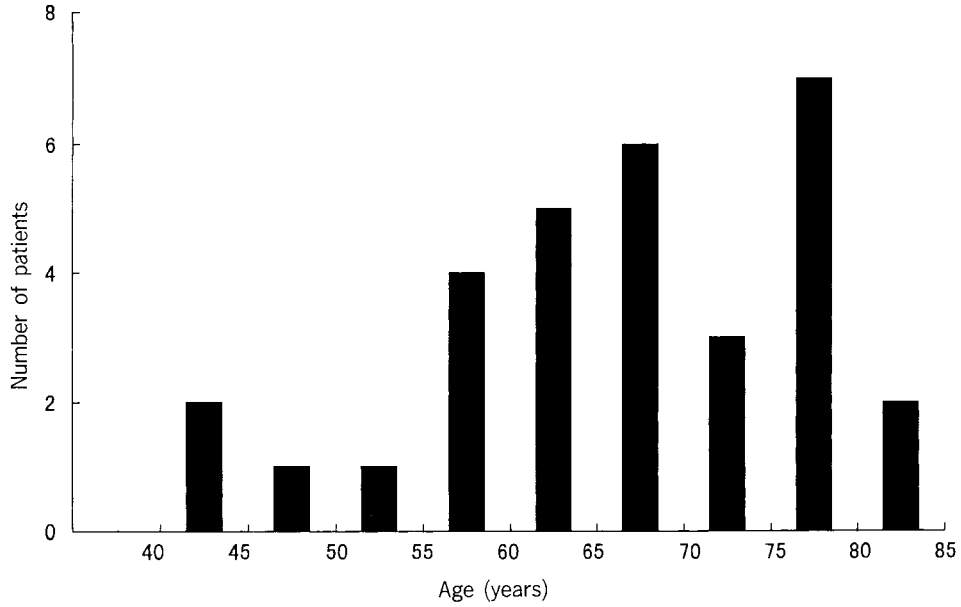

Fig. 3 Age distribution in amputees with plug-fit socket.
n = 31, patients ranged from 43 to 82 years old (66.8 ± 10.8).

Pritham (2) reported the biomechanics of the ischial ramal containment socket (IRC socket, 1990), which prevents lateral shift of the proximal part of socket, and improved stability in the coronal plane.

A new design of the polycentric knee joint was reported by van de Veen (3) in 1993 and by Chakroborty and Partil (4) in 1994. The former type had a four-bar-linkage mechanism that could be flexed under load at heel strike without losing stability. The latter had a six-bar-linkage mechanism that produced simulated normal knee motion during walking and squatting, and that permitted cross-legged sitting.

Furthermore, swing phase control study has resulted in sophisticated knee joints. Boenik (5) emphasized the importance of swing phase control with a hydraulic control system in 1994, and Nakagawa (6) developed a micro-computer-controlled knee joint (Intelligent A/K prosthesis) in 1990. Energy storing feet also improved prosthetic function. Michael (7) classified several energy storing feet according to their clinical use in 1987.

However, the actual conditions of their prescription has been scarcely reported in Japan or any other country.

The purpose of this paper is to survey the types, sockets and components of A/K prostheses currently in use in the Chugoku-Shikoku district of Japan. This is one of districts in Japan where the limb-fitting service has been very active (8).

Although the endoskeletal type has been more common since the beginning of the 1970s in Japan, one-third of the prostheses was of the exoskeletal type. Of the endoskeletal type, 87.3 % were prescribed for amputees whose period after amputation was under 25 years (Fig. 2). These results indicate that the endoskeletal type has been available for about 25 years in the Chugoku-Shikoku district.

Of the A/K prostheses, 36.9 % had plug-fit sockets. Because of the loose fitting characteristics of this type of prosthesis, the amputees could easily rotate their prostheses. This was very beneficial for the Japanese indoor lifestyle which involves sitting on the floor, especially for elderly amputees. In this study, 74.2 % of the plug-fit socket users were over 60 years old (Fig. 3). The total-contact socket has many biomechanical advantages. However, the plug-fit socket has many advantages for elderly Japanese A/K amputees in daily life. Moreover, 22.6 % of total-contact sockets were of the ISNY type. The small number of ISNY type sockets was considered to be due to difficulties associated with fitting.

Of the endoskeletal type, 85.5 % had turntables. Because A/K amputees generally sit directly on the floor (tatami, straw matting), it seems advisable to prescribe the turntable as a matter of course. We could not set the

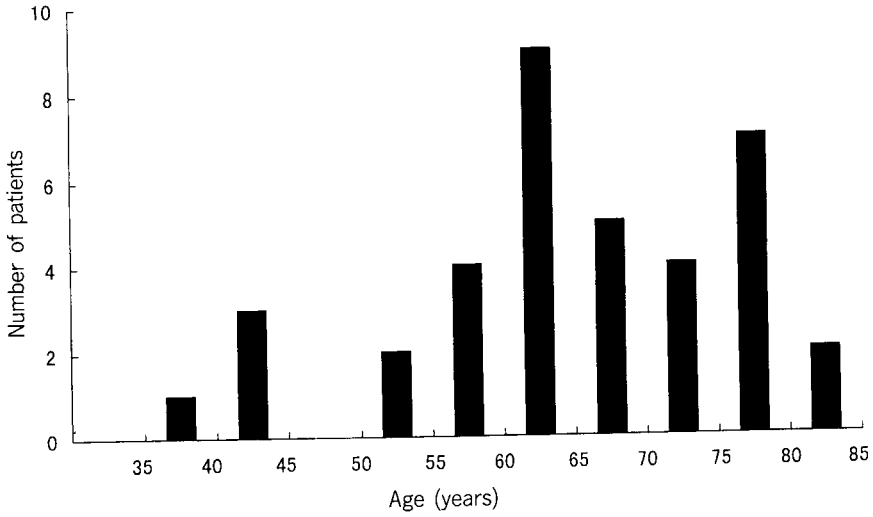

Fig. 4 Age distribution in amputees with lock-knee joint.
n = 37, patients ranged from 37 to 82 years old (65.0 ± 11.5).

standard turntable (LAPOC M0610, Otto Bock 4R45) for long A/K stumps, therefore a thin turntable (LAPOC M0620, Takasaki TG2014, Otto Bock 4R57) was required. As a result, 70.2 % of turntables were of the thin type.

Of exoskeletal and endoskeletal types, 75.9 % and 27.3 % respectively, had lock-knee joints (44.0 % of all A/K prostheses). Lock-knee joint users locked their knees during walking. Of all the lock-knee users, 73.0 % were over 60 years old (Fig. 4). Of the endoskeletal type, 63.6 % had safety knee joints which also ensured knee stability during walking. From these findings, we concluded that knee stability during walking is the most important function when selecting a prosthetic knee joint, especially among the elderly. The polycentric knee joints were prescribed for patients with long stumps so that the heights of both knee joints (prosthetic and unaffected sides) would be equal when sitting in a chair. The microcomputer-controlled knee joint was recently developed and is now available commercially. With the swing phase control function of this knee, A/K amputees can vary their walking speed. For young active A/K amputees, this type of knee joint is very beneficial and will almost certainly become popular in the future. However, its high cost (¥350,000 or roughly US$3,500) is somewhat prohibitive.

Of the exoskeletal and endoskeletal types, 72.4 % and 94.5 %, respectively, had single-axis ankles. The single-axis ankle was quite common, probably because it is the most stable during walking. The energy storing ankle-foot exhibited improved prosthetic function, such as in running or jogging more in below knee (B/K) than in A/K prostheses. A small number of this type was observed (2 Seattle feet, one Dynamic foot). Thus, it is evident that a greater stability of the ankle-foot is necessary in A/K than in B/K prostheses. Only those patients who perform heavy work used the Dollinger foot and a fixed ankle, sacrificing mobility for strength.

Of the turntables, 59.6 % were imported. Only one exoskeletal A/K prosthesis had an imported knee joint. However, 56.4 % of knee joints of endoskeletal A/K prostheses were imported. Regarding the ankle-foot, only one exoskeletal A/K prosthesis had an imported knee joint, while 69.1 % of the ankle-feet of endoskeletal A/K prostheses were imported. The high percentage of imported prosthetic components in the endoskeletal prostheses is believed to be due to an inadequate supply of domestic prosthetic components.

Recently, new designs of sockets and components have been developed due to advances in high technology. However, we should not change the prescription of prostheses, especially for long-term users, as long as the social activity of the amputee is maintained. They have mastered the characteristics of their prostheses. If advanced sockets or components were prescribed for such amputees, in expectation of improved function, it would

be unlikely that good results would be achieved. In order to manage the new prosthesis, they would have to be hospitalized for a while.

Moreover, most of the long-term users are elderly. In such cases, it is questionable whether the higher functionality of the new types of prostheses would benefit the amputees. New types of sockets and components should be prescribed as the first prostheses of the young active A/K amputees.

On the other hand, the stumps resulting from trauma are not always ideal in length, shape, skin condition, *etc.* Hirai (9) reported that 40 % of the A/K stumps resulting from trauma had some troubles in socket fitting. Patients with these stumps could not make the most of these advanced socket. In our cases, 67 out of 84 amputations were the result of trauma.

Needless to say, we do not prescribe the combination of plug-fit socket, lock-knee joint and single-axis ankle for recent amputees. And we also do not prescribe new types of socket and component for long-term users, elderly and A/K amputees with poor stump condition.

One should prescribe the prosthesis based on an evaluation of the physical ability of the amputee (age, occupation, *etc.*).

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