QUANTITATIVE ASSESSMENT FOR TRANS-FEMORAL PROSTHETIC SOCKET

Yoshitaka Kudo, Kazuma Kurosawa, Takuya Saito, Yukio Agarie, Hiroshi Otsuka, Kengo Onishi, Akihiko Hanafusa, Shin-ichiroh Yamamoto

Graduate School of Engineering and Science, Shibaura Institute of Technology

mf14020@shibaura-it.ac.jp

ABSTRACT

Background: A prosthetic leg is artificial leg used to restore the form and function for stump. Sockets are important parts of prosthetic leg, because it combines directly stump with prosthetic leg. Then, socket's manufacture is based on the complex internal organization of stump. Socket's design system without prosthetist of proficiency is required, because socket's manufacture is manual labor by prosthetist. A group of authors is aiming to develop the socket design support system. For developing the system, two type of trans-femoral socket's shape produced by prosthetists different years of experience is analyzed and assessed.

Method: Positive models of UCLA and MCCT type socket was produced by three prosthetists (years of experience, Prosthetist A:27, B:10, C:5). Shape of positive models was measured by contactless three dimension digitizer. Characteristic of UCLA model is to accommodate the ischial tuberosity and to support the stump from the medial and lateral. Characteristic of MCCT model is to accommodate the ischial tuberosity and to support the stump from the medial and lateral, anterior, posterior. All analyzing was divided into each process of socket's manufacture (eight processes in all). Cross-sectional area and volume, amount of modification, modify ratio against volume was calculated.

Findings: Amount of modification varied by process of socket's manufacture. However amount of modification was smaller MCCT than UCLA. This difference of modification's amount was assumed that it shows MCCT socket of design philosophy. In addition, amount of modification tended to increase by decreasing the years of experience. It was assumed that the experience less prosthetist is affected by method of manufacture.

Conclusion: This study revealed detailed amount of modification each manufacture process. These data was used to develop the socket design support system after this.

1. INTRODUCTION

The prosthesis is a foot artificial which used for restore the loosing original form and function by cutting in the lower limb. The prosthetic socket is one of the prosthesis components, it plays an important role in linking the stump end and the prosthesis directly. Sockets does not make a shape of the stump as it is. Shape of socket is determined based on the shape of stump of muscle, fat and bone. Therefore, there is a need for a socket manufactured specifically for each stump. Current, the femoral prosthetic socket is manufactured by manual labor of prosthetist [1].

However, shape and internal organization of stump has not been quantified in the current production process. Therefore, positive model made of plaster are used for mold of socket. However, cutting operation of the positive model has not been quantified. Qualitative and subjective manufacture method like this has become a problem. System was not depend on experience of prosthetist and be able to manufacture fitting socket has been required. Because author's group are aiming at developing this system. For incarnate it, we have been doing analyzing shape of trans-femoral prosthetic socket by measuring positive model and internal organization of stump by MRI image, simulation by FE models.

Aim of this study is to quantify for each manufacture process of the positive model correction amount in prosthetist of different experience and different socket type. Then, this result will became as base data of system developed by authors group.

2. EXPERIMENT

2.1 Experimental Sockets

Positive models used this study are UCLA type socket and Manual Compression Casting Technique (MCCT) type socket. UCLA type socket' manufacture method is as follows. First, target circumference of positive model was calculated by circumference of stump during stump measure process. Then, positive model was cut with the aim of target circumference. Characteristic of UCLA type socket is to have the support of medial and lateral.

On the other hand, MCCT type socket's manufacture

method as follows. First, stump has been added the pressure during stump measure process. Then, circumference of that stump was defined target circumference of positive model. Characteristic of MCCT type socket is to have the support of interior and exterior, anterior and posterior.

Characteristic of both sockets is to contain ischial tuberosity and be classified “IRC type”.

2.2 Experimental Subject and Prosthetist

The experimental data is collected from one above-knee amputees (left side), three prosthetist. The subject had been using trans-femoral prosthetic socket from eight years ago. Then, the subject is accustomed to use both socket.

Table 1 Subject Profile

Number	1
Age	38
Sex	male
Height[cm]	168
Weight[kg]	65
History of Usage[year]	8
Amputee Side	left

Table 2 Prosthetist Profile

Prosthetist	A	B	C
History of Prosthetist[year]	27	10	5
History of Work factory[year]	15	5.5	2
Production total number of Socket[Number]	640	40	10
Production number of Socket during recent 1 year[Number]	18	1	1

3. ANALYSIS

3.1 Measurement equipment

Positive model prosthetist manufactured was measured by Non-contact type Three-dimensional Digitizer “Artec3D (data design Co.)”. All measurement procedures were performed according to the manual

Figure 1 Artec3D (data design Co.)

3.2 Modification amount analysis

In positive model prosthetist manufactured, Shape data was measured by Artec3D amount 12 manufacture process. Example of process is “Shaving Femur” and “Shaving Rear face”. Furthermore, according to the socket manufacture manual, analysis range has narrowed down to one range of Shaving. The purpose of this attempt is improvement of analysis accuracy.

Positive model got by Artec3D was converted into point cloud model. Then, Point cloud model was been to align three-dimensionally. Criteria of alignment were pipe and reference plane (front wall and inner wall most proximal plane), femur length axis, ischial tuberosity. After determined point cloud model of reference position, all model was been to align quantitatively by ICP algorithm. ICP algorithm is principle based least-square method. Moreover, cross-sectional area and volume of two models calculated and compared. Slice interval is 1[mm]. Point cloud make 360 triangle for every 1[deg] along the outer periphery. In the same analysis range, volume difference between the pre-process was defined amount shaving.

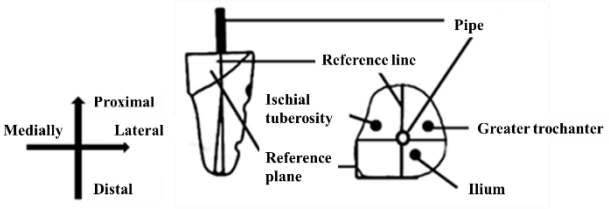

Figure 2 Criteria of alignment

4. RESULT

As a typical example, “Process 10: Shaving diaphysis of Femur” of analysis range and result was showed (Table 3 and Figure 3). And so, MCCT’s amount shaving was less than UCLA’s amount shaving. This result was consistent with previous study investigated in the last year by author’s group [2].This study of prosthetist is a high degree of skill in the order of A, B, C. Then, amount shaving and volume ratio of positive model was greater in the order of C, B, A.

Table 3 Analysis range of Sagittal plane

Prosthetist	Socket	Distance from the distal end of Positive model[mm]	
A	UCLA	90	255
	MCCT	95	260
B	UCLA	90	255
	MCCT	95	275
C	UCLA	85	250
	MCCT	95	275

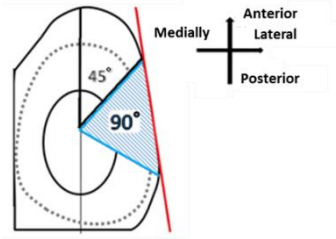

Figure 3 Analysis range of Cross-section

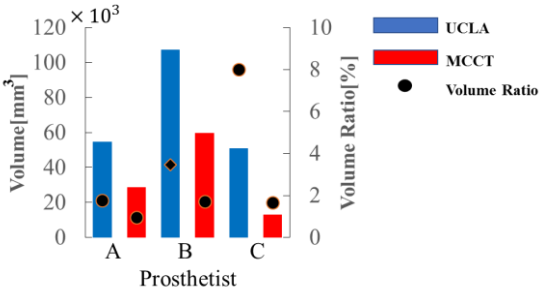

Figure 4 Amount of Shaving ("Process: 10")

Volume ratio was calculated by dividing amount shaving of this process by amount shaving of pre-process.

Amount of shaving in all process was showed (Figure 5). From this result, the same trend was obtained. But, different result was showed by part of process.

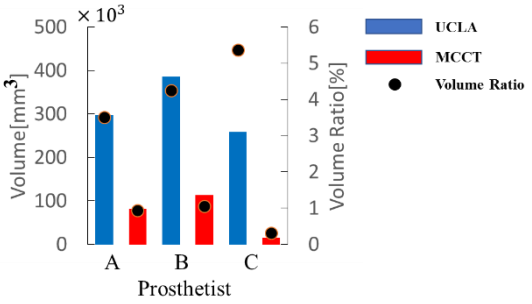

Figure 5 Amount of Shaving ("Process: Total")

5. DISCUSSION

This study revealed obscurity amount of shaving in manufacture trans-femoral socket. Change of modification was difficult to recognize until now. However, these were quantified by method of this study, and this result was applied to socket design support system.

From this result, the amount of shaving was different depending on the socket type was suggested. Also, it was suggested that has appeared design philosophy of MCCT model (Figure 5).

Throughout, that degree of prosthetist's skill and amount of shaving is inversely proportional was suggested. However different trend was showed by part of process (example: "process 15: Modification of the medially hamstring area").This result was estimated to be individuality of prosthetist. Because, design concept has to be supported by socket design support system.

REFERENCES

[1] Yukio, A., Japan Prosthetics Association Kanto Branch seminar 2007.

[2] Fumiko, T., Life Support Society Frontier lecture 515-521, 2006.

Yoshitaka Kudo received the B.E. (2014) degrees in Bio-Engineering from sibaura insititute of Technology.

He is 2nd master course, Majoring Systems Engineering and Science, S.I.T.

Kazuma Kurosawa received the B.E. (2015) degrees in Bio-Engineering from sibaura insititute of Technology.

He is 1st master course, Majoring Systems Engineering and Science, S.I.T. His study is to simulation by FE model.

Takuya Saito is 4th bachelor course, Department of Bio-Engineering, SIT. His study is to analyze internal organization of stump by MRI images.

Yukio Agarie received the B.E. (1985) degrees in Prosthetics and orthotics from College National Rehabilitation Center for Persons with Disabilities. Department of Medical Technology, Niigata Univ. of Health and Welfare.

Hiroshi Otsuka received the M.E. (1994), degrees in Mechanical Engineering from Hosei Univ. Department of Health Sciences, Univ. of Human Arts Sciences.

Kengo Ohnishi received theM.E. (1998), degrees in Mechanical Engineering from Tokyo Denki Univ. Department of Science and Engineering, Tokyo Denki Univ.

Akihiko Hanafusa received the M.E. (1983), degrees in Precision Mechanical Engineering, Tokyo Univ. Department of Bio-Engineering, S.I.T.

Shin-ichiroh Yamamoto received the PhD degree from the Department of Life Science, The University of Tokyo, in 2000. He is a Professor, department of Bio-science and Engineering, Shibaura Institute of Technology.