International Journal of Physical Education, Sports and Health 2021; 8(5): 211-214

P-ISSN: 2394-1685
E-ISSN: 2394-1693
Impact Factor (ISRA): 5.38
IJPESH 2021; 8(5): 211-214

www.kheljournal.com
Received: 15-06-2021
Accepted: 03-08-2021

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Aquasplash prosthetic leg: A case study

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Abstract
An experimental single case study was conducted with an aim of introducing a feasible and cost effective shower prosthetic leg and to evaluate the effectiveness of the new conceptual design. A 21 years old female patient who had undergone transtibial reconstruction surgery was studied to fabricate a shower prosthesis that can be worn by the amputees while taking shower. A new prosthetic shower leg was fabricated based on her measurements and her feedback was taken from the patient about the same. The feedback given by the patient showed that the new design of prosthesis is feasible ad comfortable during stump washing, taking shower and for short distance walking. Thus the design discussed in the present study can be a cost effective way to make amputees physically independent in washroom and also reduce the risk of fall and early degeneration of joints among amputees.

Keywords: Transtibial reconstruction surgery, amputation, prosthesis, shower prosthesis

Introduction
Transtibial amputations, also referred to as "below-knee" or "BK" amputations are one of the most common major limb amputations. A individual who has had a transtibial amputation retains their knee joint, which serves as a strong mechanism for lifting and lowering them [1]. A healthy knee not only leads to an ability to lift and lower things, but it also helps maintain balance [2]. The socket, shank, and foot of transtibial prosthesis are used to encase the residual limb and aid forward movement while maintaining balance [1]. There is mainly three kind of socket design is most common, these are Patellar Tendon Bearing (PTB), PTB Supracondylar (PTB SC) and PTB SC Suprapatellar (PTB SC SP). Patellar Tendon Bearing (PTB), PTB Supracondylar (PTB SC), and PTB SC Suprapatellar (PTB SC SP) are the three most common types of socket design. Sockets are used with endoskeleton or exoskeleton shank with different types foots and suspensions [2].
Because of its metal parts, the prosthesis that amputees wear on a daily basis cannot be taken into the bathroom or any other wet place. Furthermore, it is dangerous for amputees to use their sound side limb to enter and exit a shower or other bathroom where the floor can be wet [3]. As a result, the most realistic solution for an amputee is to provide an extra shower prosthesis, which uses parts and materials that are specially designed to withstand water exposure. It needs to have a rubber outer sole that provides solid grip on wet floors and prevents aquaplaning, as well as a body extension that allows amputees to stand stable.
However, such prostheses are either unavailable or financially unaffordable. As a result, the aim of this experimental single case study was to introduce a viable and cost-effective shower prosthetic leg and to assess the efficacy of the new conceptual design.

Case Report
A 21 years old female patient who had undergone transtibial reconstruction surgery was considered to assess the efficiency of newly fabricated prosthesis. The patient had met with a road traffic accident at the age of 7 years, after which she had undergone reconstructive surgery. After a year of the surgery, the patient started using transtibial prosthesis; the prosthesis being used by the patient was Endoskeletal prosthesis; PTB SC type socket design and modular components with SACH foot & soft cosmesis. However, the prosthesis imposed a great difficulty for the patient while in shower due to its lack of water proof characteristic. Every time she hopped into shower, she needed manual assistance removing the prosthesis which affected her level of independency.

Along with that, she was compelled to take shower while sitting on the chair which she was not comfortable with. So affordable additional shower prosthesis with available water resistant material was made and tested on her to ease her discomfort, the details of which are given below.

Fabrication of Aquasplash

Transtibial PTB SC (Figure 1) was used to secure the stump and provide anatomical suspension. The socket was used without liner and drill was made at the end of socket to circulate water from socket to lower shin extension part. Technical protocols involved fabrication of Transtibial PTB SC socket with shin extension (Figure 2) and foot plate (Figure 3) for BK amputee and moulding and modification of the same.

Casting was taken in high sitting position with 10-12 degrees of knee flexion. Clean film was wrapped over the residual limb from distal to proximal (over supracondylar region). The following landmarks were marked (Figure 4); border of patella, Patellar Tendon, Tibial Tuberosity, Crest of Tibia, Medial Tibial Flare, Head of fibula, Cut end of Tibia, Lateral tibial tubercle. A six inch bandage was used to obtain the negative cast (Figure 5). During casting, the hand position was maintained for Patella Tendon Bearing supra condylar socket.

Positive Cast (Figure 6) was poured with POP mixture and was left to set. All landmarks over the negative mold were reinforced and irregularities were matched. Clearance was given over the bony prominence area and patella tendon channel and popliteal fossa shape was made. Pressure was given over the pressure tolerance areas following dimensional, linear, circumferential measurements. After that moulding was done using the 4mm polypropylene sheet and posterior sealing and suctioning was done with care. (Figure 7) For the fabrication of shin extension, impression was taken from middle to end of socket and extended while maintaining leg length for shin extension. Modification and moulding was done. Shin was trimmed maintaining the prosthesis required height.

A cutout was left antero-posteriorly in the proximal part so that stump could be pulled distally by stockinet while donning prosthesis. Distal conical part was attached to foot plate with help of nut bolt. Foot plate impression was taken from distal aspect of shin extension. Anterior and posterior aspects of flanges were extended as dorsum foot plate to prevent fall off and achieve stability. Both ends were made flat to ensure stability on ground.

Overlapped moulding was done for flanges and dorsum foot plate. Both flanges of foot plate were trimmed and grinded properly. After that, both foot plates were attached together. The overlapped flanges were secured with distal shin extension part and both surfaces were attached with nut bolt antero-posteriorly and medio-laterally in alternate position. Socket was mounted on the proximal extension part. By maintaining prosthesis length and contour, socket was attached to shin extension. Anteriorly one and posteriorly two wings and nuts were used as fastener for socket and shin. Nut head was kept flat so that it doesn't hurt stump.

Fig 1: TT PTB SC Socket

Fig 2: Shin extension

Fig 3: Foot plate

Fig 4: Frontal view of residual limb with landmarks

Fig 5: Negative cast of PTB SC (sagittal & frontal view)

Fig 6: Positive mold of PTB SC (frontal & sagittal view)

Fig 7: Moulding of TT PTB SC socket (frontal & sagittal view)

Result

A socket trial was conducted before assembling prosthesis and it fitted snugly on patient stump. Afterwards, a second trial was taken with complete assemble of aquasplash prosthetic leg and it was found to be well fitted with height perfectly matched with sound leg. Instruction was given for don and doff along with gait training. Shin extension transmitted whole weight to the ground and foot plate absorbed the shock and provided forward progression while walking short distance. Therefore patient was able to walk the minimal distance of bedroom to bathroom comfortably. While pouring water during shower, the water flowed through socket to the shin extension and foot plate. It was easy for patient to take shower with the prosthesis. It also prevented patient from slipping off ground as sole had firm grip against the ground.

Discussion

Since no liner was used in the current study, the patient initially reported discomfort and was insecure of the prosthesis during the first trial. However, once the silicone pad was inserted at the distal socket, the patient's concerns were immediately resolved. As the patient stated, the prosthesis was well-fitting and tightly aligned.

If the user experiences pain or discomfort when wearing the prosthesis, a cutout may be placed in the socket region where the user is experiencing pain. Instead of having all parts of prosthesis, only a socket and an extension component for the flow of water can be made in an existing prosthesis, saving both time and money. It is also recommended that a cuff suspension be used at the proximal part of the socket to reinforce the stump's grip on the socket. It is also recommended that leather be replaced with a thin, flexible polypropylene sheet. Acrylic sheet, which can be easily molded and is more durable than polypropylene, can be used to create this prosthesis. It can be used with plastic or other light-weight fasteners, which are stronger and more aesthetically pleasing than metal fasteners.

When hopping on one leg or using crutches, amputees often fall in bathrooms where water and loose bathroom mats pose a threat for slipping [4]. Even a non-amputee will find it difficult to get in and out of a bath with just one lower limb supporting them. Increased strain on the sound side limb from activities such as hopping on it or carrying the entire body weight while not wearing prosthesis may lead to earlier degeneration of the sound side limb, especially the knee and hip joints, over the amputee's lifetime [5].

Along with that; because of the hazardous conditions in the tub, some amputees stop showering and instead dry clean on their beds. There is a chance of irritation or infection around the skin of the stump due to insufficient stump washing [6]. Further amputation may result in bacterial and fungal infection on the stump [7].

As a result, creating a water-resistant prosthesis that can be used in the shower and teaching an amputee how to use it is an essential aspect of rehabilitation. It not only assists amputees in being self-sufficient, but it also decreases the risk of falling, early limb degeneration, and infection.

The current report, however, had a few shortcomings. The prosthesis was designed for a specific function so its uses are limited. Unless the metal parts used in the study are regularly coated, they can rust after a certain amount of time. The prosthesis' construction can be complicated due to the various parts it contains. And, since the prosthesis was originally designed without a liner or suspension, special attention should be paid to the user's discomfort and any possible adjustment needs to be made.

Conclusion

The aim of this study was to implement and test a new type of prosthesis that can be used for stump washing, showering, and short distance walking. The patient's feedback in this study indicates that the designed prosthesis met its objectives.

The study concludes that the designed prosthesis can be well used in shower and is cost effective for general population. However, fabricating and modifying only the socket and extension parts of the prosthesis would simplify the design and increase amputee acceptance. It is also advised to use the modified polypropylene cuff suspension to secure the gait and better anchor the stump with the socket.

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