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Short Communication

Development of an Adjustable Prosthetic Ankle-Foot Adapter: A Prototype

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ABSTRACT

Prosthetic ankle-foot systems cannot adapt automatically to changes in shoe heel height. These systems can be altered using changes in alignment to properly orient the roll-over shape of the ankle-foot-shoe system. However, these changes require manual adjustments and, with most systems, require tools to make the adjustments. The use of heel-height-adjustable prosthetic ankle-foot systems may be advised for persons who would prefer to use shoes of different heel heights and who understand the necessary alignment changes needed for switching between these shoes. Further work is needed to examine the consequence of using shoes of different heel heights without changing the alignment of the prosthesis to accommodate these heel heights. The inability of prosthetic ankle-foot systems to adapt is perhaps since these systems have set points that cannot be altered without changes in alignment. Future designs of ankle-foot prostheses could make attempts at systems that can adapt automatically to changes in shoe heel height. This feature could allow persons using prostheses the ability to walk using a variety of shoes (and to walk without shoes) comfortably and without needing manual adjustments of their prostheses. The use of similarly oriented roll-over shapes would presumably yield similar loading moments to the residual limb socket, which may be perceived as a similar comfort level by the prosthesis user. The ability to automatically adjust for different heel heights may also lead to automatic adaptability for walking on different ramped surfaces.

Keywords: Prosthesis, Component development, heel height, Ankle foot adapter, Adjustable.

INTRODUCTION

Prosthetic prescription for patients with lower limb amputation is primarily based on empirical knowledge (1). In lower extremity prosthesis, the prosthetic feet and ankle designed for unilateral below-knee amputee have yet completely restored the body forward propulsion, body support, and leg swing initiation normally provided by the ankle muscle during walking (2). The development of scientifically based clinical guidelines plays a vital role to develop the rehabilitation sector more consistently and efficiently (3). In the case of lower extremity amputees, it is experiencing certain pathological changes and exhibit higher metabolic demands. More specially, trans-tibial amputees using passive prosthesis display abnormal gait patterns due to part of the lack of calf muscle and fully functioning ankle joint. Among the joint disorder for which unilateral transtibial amputees have increased susceptibility is knee osteoarthritis due to repeated stress. The many prosthetic feet currently available for the individual with a transtibial amputation differ in heel, ankle, and forefoot mobility because of variations in design and mate (4). Although these variations introduce functional differences, the prosthetic feet have an underlying similarity that of providing the fundamental functions required for walking. The human ankle and foot are unique in many ways. The center of gravity of the body may be imperceptible and unconsciously shifted by actions within the ankle and foot. The natural flexibility of the human foot and ankle combine to provide selective universal motions. The casual study of the human leg and ankle during walking gives an illusion of ease and simplicity in their respective function. The skeletal structures of the leg, the bones, functionally severe in three distinct ways i.e. support mobility, and stabilization for the body with major articulations at the hip, knee, and ankle joints. Therefore, it is necessary to develop an ankle-foot emulation system that provides movement in this segment. Moreover, this adaptor is not new in the field of prosthetics but its approachability towards simple design creates enthusiasm for the development of such devices.

Many types of a prosthesis having adjustable ankle adaptor are designed for better lower limb ambulation. The purpose of the limb is to enable mobility to amputees and help them in standing, kneeling, and maintain balance. It includes the design and development of knee joint, adjustable shank, ankle joint, and foot. Although the devices optimally assisted to various functions, the cost and easily available material are still far to reach. The spectrum of technologies exists to measure ankle joint dorsiflexion range of motion. Performance goals include similar or superior walking of persons with transtibial amputations using the prototype as compared to commercially available prosthetic foot and ankle components on a level surface and superior function when using the prototype on inclined and declined surfaces. Following this previous design, we have taken an attempt to design a new mechanism of ankle adjustable adapter. The ankle mechanism is often studied and compared based on how they substitute for human foot and ankle submission. Modern prosthetic practice includes a growing array of foot /ankle mechanisms designed that after a wide spectrum of function, indication and new design and material have added properties and motion. This constant innovation requires a greater knowledge of human foot and ankle functions and more descriptive terminology. When recommending prosthetic foot/ankle mechanism of patient.

Therefore, we have taken an effort to fabricate a prosthetic ankle unit which is provided the adjustment of using various footwears as well as facilitated barefoot walking. Generally, this design has adopted the required height adjustment to the trans-tibial amputee. Able-bodied ambulators frequently wear shoes of different heel heights with little or no difficulty. Several studies have examined the effects of shoe heel height on the gait of able-bodied persons. But the fact is the amputee always constraints of footwear. A problem faced by the lower extremity community, we will try to design such a device for heel height adjustment concerning the different footwear. Although the existing prosthetic devices provided similar functions while the new design is just a method to adopt the simple method rather than a complex one. In addition to this, it is the exercise of our available material which is cheaper and fabricated simply. The rigorous effort makes it more comfortable and functional and it may accept the patient's mindset.

MATERIALS AND METHODS

SUBJECTS

The project began as an effort to construct a relatively lightweight, heel height adjustment, different heeled shoes can be used, strong, lower-limb prosthesis with a high comfort range, specifically designed to heel height adjustment function with an ALIMCO lower-limb prosthetic system. The patient was an adult female unilateral trans-tibial amputee who presented at NIRTAR for fitting of prosthesis. The amputee was an experienced prosthesis user, with a standard residual stump, below-knee amputation. Previously she had been provided with unilateral BK prostheses at other prosthetic fitting centre using traditional exoskeletal construction. She had discarded these due to its no height adjustment functions, different shoe heel height interchangeable not possible. The same patient was successfully fitted with the endoskeletal prostheses with the new heel height adjustment components developed at SVNIRTAR.

This patient pursued to use a variety of heels in her daily life activities which required either to frequently change the prosthetic alignment or to change prosthetic foot. Past prostheses, without any height adjustment design and styles, had not allowed using different heels.

FABRICATION TECHNIQUES

This new and simple design generally needs a proper design blueprint along with an empirical thought process. A proper blueprint led to a better device with less error. As this concept was taken from existing devices, we made it simple with some innovative modifications. For designing this device, we took reference to the pyramidal transtibial kit of ALIMCO.

The blueprint intended that there is a base plate with a provision of a T-shaped rod anteriorly projected upward, a SACH foot pyramid adaptor along another upper plate attached in a hinge. Both plates are moving upward or downward by adjusting the nut in the T- shaped rod. (fig.1)

This design was fabricated from the following components such as:

- ALIMCO pyramidal kit
- Modified pyramid
- 6mm aluminium plate
- SACH foot
- 6mm bolt
- 6mm nut
- 9mm m8 bolt
- Washer

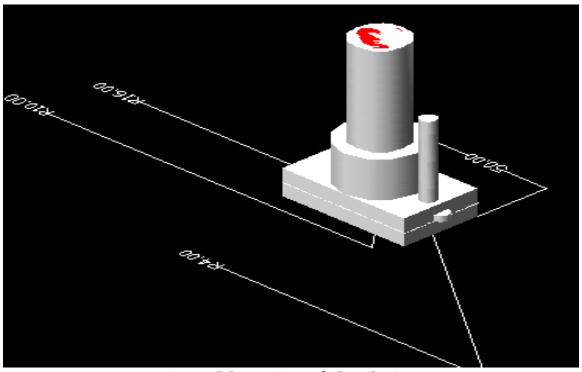

Fig-1- blueprint of the design

At first, two 6mm aluminium plate was taken as the same dimension. The purpose was to create a strong base on which the mechanism rests. The two plates are attached further to intend for making a groove in the anterior portion as receiving one T-shaped rod. (Fig.3). This groove was made of 5 mm diameter for facilitating the pivotal movement of the 4mm dia T-shaped rod as shown in the figure. Both plates were fixed and commonly known as a base plate for this mechanism with accommodating the part of the T- shaped rod. After completing this segment, the pyramid foot adaptor was taken for modification. The foot adaptor was made in a rectangular shape through welding of some metal pieces as it provides a supportable base for attaching a hinge. A mild steel plate was taken in the approximate same dimension as the SACH foot adaptor and again it was constructed in such a manner that it accommodated the upper contour of the adaptor. Also, its upper portion received the female pyramid adaptor of the transtibial component. Further, both the upper part and lower part of the modified adaptor were attached with a hinge on the posterior side to provide a uniaxial movement in the sagittal plane.

The completion of the modified pyramid adaptor is now fixed with the base plate & SACH foot through the M8 bolt i.e. SACH foot bolt. For this, a 9mm diameter hole was made on the center of the base plate. Similarly, for accommodating the threaded part of the T-shaped rod a 6mm diameter hole was made on the anterior part of the modified male pyramid adaptor. The T-shaped rod is adjusted with the help of two nuts for upward and downward movement of the upper part of the male pyramid adaptor. In between these two pyramids, a washer must be inserted for shock absorption and to eliminate metallic sound. Finally, it was attached to the rest of the components. Then the alignment was adjusted with the footwear such that the pylon was almost vertical to the ground. (Fig.6)

The total concept prosthetic ankle-foot system was tested in different foot wears having different heel heights with the adjustment nuts. It was observed that it can be adjusted simply by hand though used by tools was inevitable.

Patient information: -

Amputation Level: Transtibial
Impact Level: Low to Moderate
Maximum Patient Weight: 100kg (220lbs)
Sizes: 22-28
Weight of Foot: (Size 27) 710g (25oz) w/ Pyramid and Foot Cover
Build Height: (Size 27) 92mm (3 5/8") w/ Pyramid and Foot Cover
Heel Height: Adjustable up to 50mm (2")
Adapter Options: Male Pyramid
Clearance: -
Male and female pyramid versions: -

- ❖ It can give a maximum 20^0 plantarflexion, 50mm (2'') heel height clearance, and 10^0 dorsiflexion.
- ❖ Foot clearance is given 10mm (3/8'').
- ❖ Clearance between built height and foot 92mm ($3^{5}/^{8'}$)

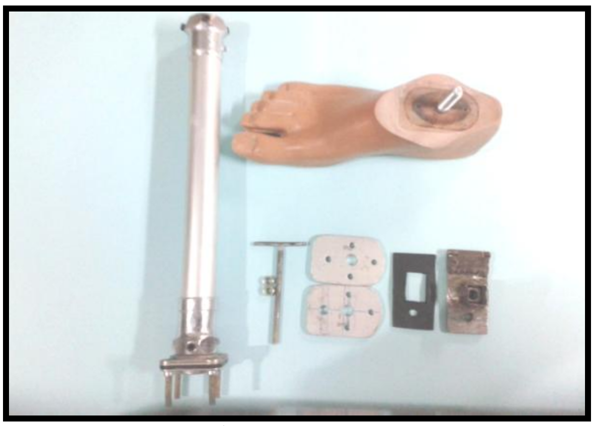

Fig-2-components

Fig-3- groove of the aluminium plate

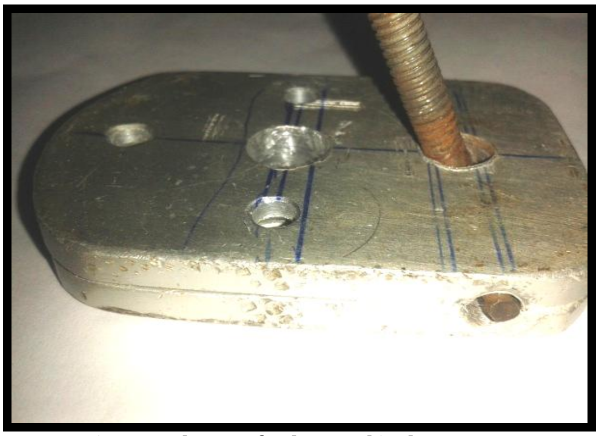

Fig-4-attachment of t-shape rod in the groove

Fig-5-side view of the attachment of adjustable adapter in foot

Fig-6-Final component

RESULTS AND DISCUSSION

Lots of people love their shoes. But swapping heel heights throughout the day can pose a problem because of the way the foot is lined up with the socket. The simple answer is it can give heel height adjustability by the locking mechanism. Whether boots, running shoes, sandals, heel sandals, and dressy heels- enjoy the freedom to change shoes quickly and easily. The nut was adjusted and changed between 0-2”/5c.m heel height adjustable and correct alignment of the prosthesis is maintained. The ankle can also be repositioned in a similar way to accommodate up or down heel slopes, changing back for level ground. The trial on the patient was done successfully with barefoot walking and sports shoes. Although it was the first trial, he felt little discomfort initially during walking. Gradually he understood the mechanism and self-motivated to adjust the adaptor. There was a trial of a wide variety of shoes with different heel heights.

Although able-bodied persons seem to adapt automatically to shoes of widely different heel heights, lower limb prosthesis users (e.g., transtibial prosthesis users) are often restricted to the use of a narrow range of heel heights. When the shoe heel height is changed beyond this small range, an alignment change in the prosthesis is usually necessary to accommodate the higher or lower heel height. Shoe heel height is probably the single most important factor of shoe fit as regards prosthetic foot function and once a prosthesis has been aligned and fabricated, the patient should not significantly increase shoe heel heights unless an appropriate wedge is added inside the shoe. Some prosthetic systems have been developed to allow the prosthesis user the ability to change the "resting" level of dorsiflexion of the ankle-foot system - or "set point" - to adapt to changes in shoe heel height. However, these systems require manual methods for setting the alignment and are not automatic as in the case of the intact able-bodied ankle-foot system.

For the basis of this study, prosthetic ankle-foot systems cannot adapt automatically to changes in shoe heel height. These systems can be altered using changes in alignment to properly orient the roll-over shape of the ankle-foot-shoe system. However, these changes require manual adjustments and, with most systems, require tools to make the adjustments. The use of heel-height-adjustable prosthetic ankle-foot systems may be advised for persons who would prefer to use shoes of different heel heights and who understand the necessary alignment changes needed for switching between these shoes. Further work is needed to examine the consequence of using shoes of different heel heights without changing the alignment of the prosthesis to accommodate these heel heights.

The inability of prosthetic ankle-foot systems to adapt is perhaps since these systems have set points that cannot be altered without changes in alignment. Future designs of ankle-foot prostheses could make attempts at systems that can adapt automatically to changes in shoe heel height. This feature could allow persons using prostheses the ability to walk using a variety of shoes (and to walk without shoes) comfortably and without needing manual adjustments of their prostheses. The use of similarly oriented roll-over shapes would presumably yield similar loading moments to the residual limb socket, which may be perceived as a similar comfort level by the prosthesis user. The ability to automatically adjust for different heel heights may also lead to automatic adaptability for walking on different ramped surfaces.

CONCLUSIONS

We conclude that the ankle-foot adapter was very preferable for prosthetic ankle-foot systems. It could not adapt to small changes in shoe heel height without experiencing changes in the orientation (in forwarding shifting) of their roll-over shapes. An alignment change can be made to properly orient the roll-over shape of the ankle-foot-shoe system. When wearing shoes of different heel heights, but this change requires a manual adjustment of the prosthesis. The use of similarly oriented roll-over shapes would presumably yield similar loading moments to the residual limb socket, which may be perceived as a similar comfort level by the prosthesis user. The ability to automatically adjust for different heel heights may also lead to automatic adaptability for walking on different ramped surfaces. Results show variable levels of limitation between the biological and the prosthetic roll-over shapes. As a result, we believe we can use roll-over shape testing to develop a prosthetic adjustable ankle adapter foot for the needs of developing nations by simulating the performance of an anatomical foot.

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