EC ORTHOPAEDICS
Research Article

Assessing the Performance of a Trans-Tibial Prosthesis with Adjustable Socket Volume

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Abstract

Introduction: Trans-tibial prosthesis is an artificial leg used by a below-knee amputee for ambulation. It mimics the human leg and tries to replace the form and functions of human leg as effective as possible. It has different components and socket is one of the major components which connects the stump (remaining part of the leg) to the prosthesis. Amputees face the challenge of discontinuing the use of their artificial limbs when they gain weight and their stumps size increases that it can no longer enter the socket. This had made the need to look for ways of expanding the volume of prosthesis socket when the need arises very pertinent.

Aim: Aim of this study is to assess the performance of newly designed trans-tibial prosthesis with adjustable socket volume to determine if it preforms intended function(s) satisfactorily.

Materials and Methods: POP bandage, POP paste, resin, catalyst, hardener/accelerator, stockinette, pylon, prosthetic foot, foot and socket adapters were used to fabricate the prosthesis. A mechanical means of adjusting the prosthetic socket was also incorporated into it. Performance of the prosthesis was tested using four parameters as fitting, stability/balance, pistoning and ability to clear ground.

Results: The prosthesis was tested on four amputees. Three of the amputees reported no pain, while one reported little pain during fitting/alignment. 4 amputees had good stability/balance when functioning with the prosthesis. The four amputees had no pistoning effect. One had very good ability to clear ground while others have good ability to clear ground during ambulation.

Keywords: *Assessment; Performance; Prosthesis; Adjustable; Socket*

Introduction

Prosthesis is an artificially made substitute for a limb lost through a congenital defect (present at birth), accident, illness, or wartime injury [1]. It is an artificial device that replaces a missing body part, which may be lost through trauma, disease or congenital conditions [2]. Lower limb prosthesis is an artificial leg that replace part of the leg that had been lost. It takes over the form and functions of the lost part of the leg [1,3]. Trans-tibial prosthesis is a lower limb prosthesis that replaces the tibia part of the leg when fitted. Over the years, there has been different efforts and studies to improve the design of artificial limb, in order to enhance the functions of amputees with prosthesis [1,2,4]. The conventional trans-tibial prosthesis available in our clime do not have provision for adjustment of prosthetic socket volume, and does not permit amputees to continue using their trans-tibial prosthesis when they gain weight across the volume of their stump. This makes it expensive for amputees to acquire and sustain the use of lower limb prosthesis [5-7]. This is also applicable to pediatric amputees who will often require to change their lower limb prosthesis because they are still growing and yet to attain ossification age.

Limb loss as also known amputation poses challenges to individuals, owing to compromise in physical activities and associated psychological depression. It is often considered as a major deformity, coupled with the decreased or absence of mobility without aids and dependence on others for daily life activities [8].

The need to have adjustable prosthesis had discouraged mass production of lower limb prosthesis, since amputees cannot purchase already fabricated trans-tibial prosthesis and adjust it to their peculiarities and measurements.

It is these challenges faced by both the amputees and rehabilitation team that informed this research study to look for ways of adjusting the socket component of a trans-tibial prosthesis, so that amputees can be rehabilitated in an improved and cheap way.

Materials and Methods

The materials used to fabricate the prosthesis are trans-tibial amputee, POP powder, POP bandage, stockinet, resin, hardener (methyl ethyl ketone peroxide), cobalt/catalyst (naphthenate), pylon, foot, socket adapter, foot adapter and adhesives. The materials used to test/assess the artificial limb are amputees, unobstructed space, skilled gait analysis professional and the designed lower limb prosthesis.

Result

Table 1 shows the performance test of the designed trans-tibial prosthesis when the amputee (case 1) whose measurements was used to fabricate the prosthesis and other amputees (cases 2, 3 and 4) whose measurements were not used to fabricate the prosthesis functioned with the trans-tibial prosthesis.

Parameters	Case 1	Case 2	Case 3	Case 4
Fitting of the prosthesis/static alignment.	No pain	No pain	No pain	Little pain
Stability/balance of the amputee with the prosthesis when standing.	Good stability	Good stability	Good Stability	Good Stability
Pistoning of the prosthesis during ambulation	No pistoning	No Pistoning	No pistoning	No pistoning
Ability of the amputee to clear the ground when walking with the prosthesis.	Very Good ability	Good ability	Good ability	Good ability

***Table 1:** Functionality test of the fabricated trans-tibial prosthesis on selected three amputess (cases).*

Key:
Pain: No pain, Little pain, Sever pain, excruciating pain.
No pain: This is classified as when there is no feeling of pain at all.
Little pain: This is classified as when the amputee feels a minor pain when wearing or adjusting the prosthesis, of which the pain can be nglected.
Severe pain: This is classified as when the amputee feels a contineous pain that cannot be nglected.
Excruciating pain: This is classified as when the amputee feels serious and intolerable pain that can lead to shock.
Stability/balance: Not stable, little stability, good stability, very good stability.
Not stable: This is classified as when the amputee cannot stand with the prosthesis.
Little stability: This is classified as when the amputee can achieve double stance support, take few steps before staggering.
Good stability: This is classified as when the amputee can achieve both double stance and single stance support, take as many steps as possible.
Very good stability: This is classified as when the amputee can achieve all in good stability, in addition to walking fast, changing gait speed and running.
Pistoning: No pistoning, little pistoning, serious pistoning, very serious pistoning.
No postoning: This is classified as when there is no form of pistoning at all.
Little pistoning: This is classified as when there is a minor pistoning that does not alter functions and can be nglected.
Serious pistoning: This is classified as when the amputee's stump almost pulls out of the socket during swing phase, that functions are altered and it cannot be nglected.
Very serious pistoning: This is classified as when the amputee's stump pulls out of the socket completely during swing phase, that functions are greatly altered and it cannot be nglected.
Ability to clear ground: No ability, Little ability, Good ability, Very good ability.
No ability: This is classified as when the amputee cannot clear the ground at all.
Little ability: This is classified as when the amputee drags his/her foot a bit that the toes sleeps through the ground to achieve ground clearance.
Good ability: This is classified as when the amputee's toes does not touch the ground at all during foot clearance.
Very good ability: In addition to the toes not touching the ground during foot clearance, amputees can vary walking speed when classified as having very good ability to clear the ground.

Figure 1 shows a graph and slope of stump's circumferential measurements against the medial-lateral and anterior-posterior distances for case 1 amputee.

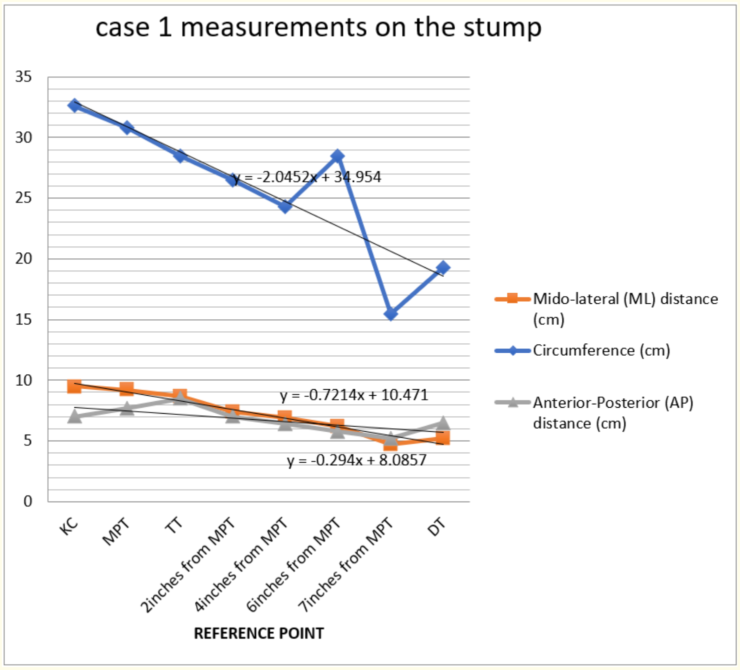

Figure 1: *Graph of circumference against medio-lateral and anterior-posterior distance for case 1.*

Figure 2 shows a graph and slope of stump's circumferential measurements against the medial-lateral and anterior-posterior distances for case 2 amputee.

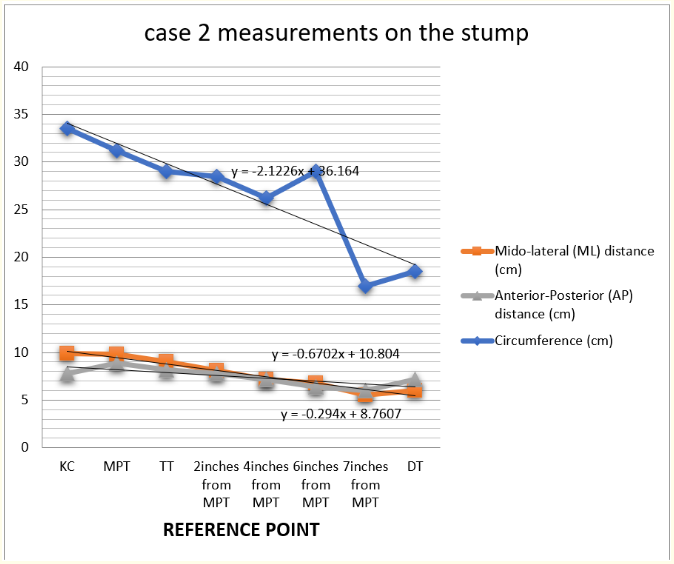

Figure 2: *Graph of circumference against medio-lateral and anterior-posterior distance for case 2.*

Figure 3 shows a graph and slope of stump's circumferential measurements against the medial-lateral and anterior-posterior distances for case 3 amputee.

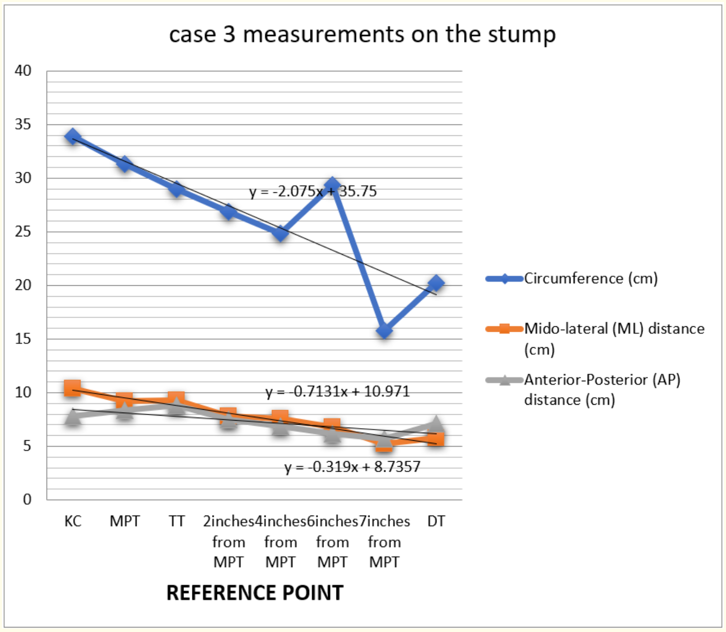

Figure 3: *Graph of circumference against medio-lateral and anterior-posterior distance for case 3.*

Figure 4 shows a graph and slope of stump's circumferential measurements against the medial-lateral and anterior-posterior distances for case 4 amputee.

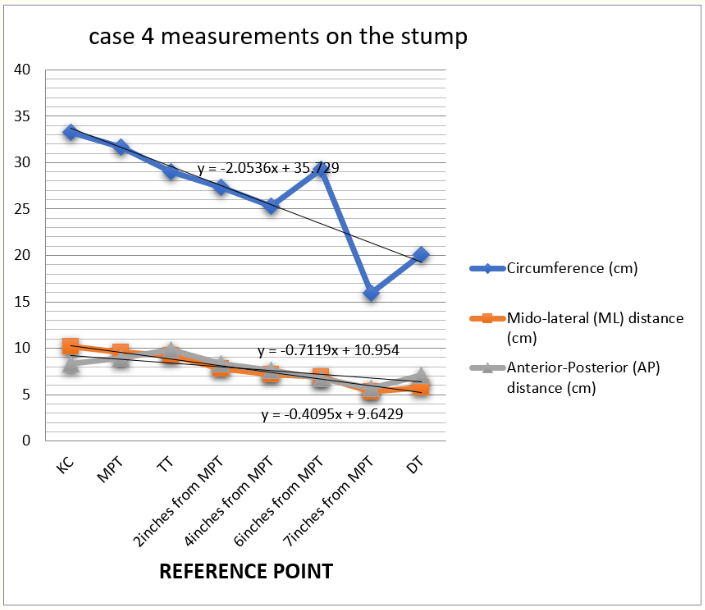

Figure 4: *Graph of circumference against medio-lateral and anterior-posterior distance for case 4.*

Table 2 shows the comparison of the graph slope of case 1 and others (cases 2, 3 and 4). The comparison helps to determine the difference in their body measurements, so as to determine the acceptable range of difference in body measurements for different amputees to use the same trans-tibial prosthetic socket.

The table 2 shows the difference in slope of circumferential measurement of the stump plotted against medio-lateral distance in case 1 and others is within the range of 0.3 to 0.5 and the difference in slope of circumferential measurement of the stump against Anterior-posterior distance in case 1 and others is within the range of 0.6 to 1.4. This implies, for an amputee to use lower limb prosthesis with adjustable socket volume fabricated with another person's measurements, the difference in the slopes of their stump's circumference plotted against medio-lateral and anterior-posterior distances should be within the range of 0.3 to 0.5 and 0.6 to 1.4 respectively.

	Case 1	Case 2	Case 3	Case 4
Slope of circumference against ML distance	9.758	10.1338	10.2579	10.2421
Slope of circumference against AP distance	7.7917	8.4667	8.4167	9.2334
Difference b/w Slope of circumference against ML distance case 1 and others		0.3758	0.4999	0.4841
Difference b/w Slope of circumference against AP distance case 1 and others		0.675	0.625	1.4417

***Table 2**: Table showing comparison of the slope of case 1 and other cases.*

Conclusion

Many research studies have been conducted on how to improve the design and fabrication of lower limb prosthesis with emphasis on functional enhancement. Walke KM and Pandure PS in 2017 worked on Mechanical Properties of materials used for prosthetic foot. Samuel Terrazas Quezada in 2017 did a research work on how to improve prosthetic socket design. Andrysek J also carried out a research study in 2010 to assess the level of technologies in the design and fabrication of lower limb prosthesis in developing countries. This study had also contributed its quota to the research need of enhancing amputee's functions with prosthetic limbs and getting a better amputee's rehabilitation outcome through incorporation of technologies. The adjustable socket component of the prosthesis solved the challenge of recurrent need of artificial limb by amputees when stump volume increases.

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