# Socket design and manufacture and prosthesis validation through Gait Analysis

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## INTRODUCTION

The lower limb prosthesis is made of three principal components: the liner, the socket and the foot. The liner, the interface between socket and stump, has to protect the stump from injuries and loads that the stump suffers during walking. It is made of soft and elastic material and the level of stump comfort depends on this. The socket is the custom made prosthetic component, obtained through the plaster cast on the stump. Socket is the most important prosthesis component: it has the function to contain the residual limb of the amputee, and to permit the unloading of weight during gait and to assure both stump comfort and prosthesis functionality; in fact a socket incorrect design may generate heavy pressures on stump and so cause skin abrasion, which produce patient's suffering conditions till the impossibility of socket wearing.

The foot's material is carbon fiber, produced through technologies from aeronautic and military industry. The foot represents the active prosthetic component: it stores and releases the energy and it reduces the stump traumas. During the prosthesis assembly, after socket production, the next important phase is the alignment of the components: the prosthesis must replicate as much as possible patient healthy leg, both considering the natural varus or leg valgus, and the possible foot intra o extra-rotation. It happens that after the laser static alignment prosthesis does not fit at the best, so the orthopaedic technician control the component regulation during the dynamic alignment, observing patient gait and following his indications.

Another important step is the prosthetic foot choice to assemble with the prosthesis: nowadays every important industry in the prosthesis component field has a peculiar foot to offer. Feet are different accordingly with user target, considering weight, shoes number and the dynamic level of patient.

## AIMS AND OBJECTIVES

The activity aim is to explore the complete socket production (by Ortopedia Panini) and prosthesis assembly process, considering the under-below knee prosthesis production, till its functional validation through the Gait Analysis system. This activity examines the behaviour of a new foot produced by Otto Bock, 1C30 Trias® Plus, using the Gait Analysis. The gait evaluation of amputee patient allows to acquire information concerning subject posture and the functionality of the prosthesis. We performed our test in the MBMC Lab, Laboratory of Movement and Motor Control by Politecnico of Milan; the laboratory is equipped with the Smart Motion Capture System, and a Kistler dynamic platform, which allow the analysis of both cinematic and kinetic Gait parameters.The output of Gait Analysis tests returns information about functional evaluation and comfort of the prosthetic device. Low differences between amputee's gait, compared to the normal subjects' one, indicate the best performance of prosthesis. The performance of Trias® prosthetic foot can be obtained like power output, power input rate.

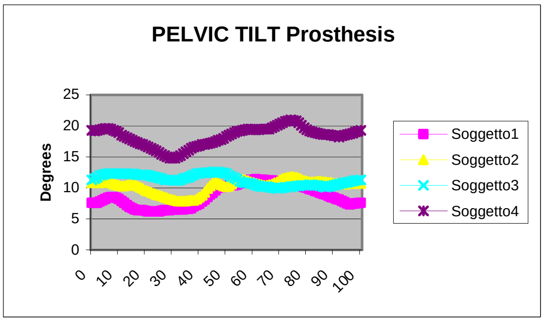
## METHODS

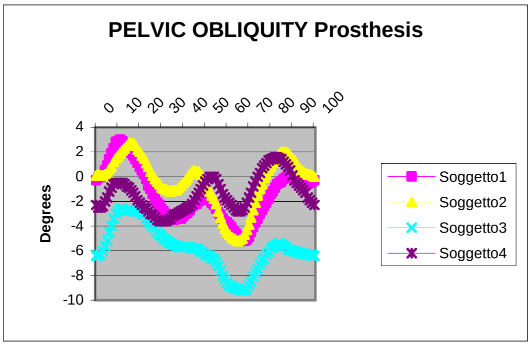
The subjects studied in this work are four trastibial amputees, three men and a woman, from 25 to 40 years old. All of them wear prosthesis for more than 10 years, therefore they have a lot of confidence with the device and they are able to judge new prosthetic components. The four prosthetic devices were completely made specifically for this study. Trias ® prosthetic foot was assembled without the cover, and used without the shoe, in order to analyse the foot morphology under loads during walking, and consequently the deformation of prosthetic foot laminate.

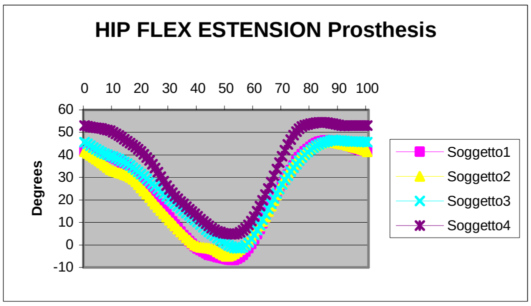
The performance area is 2,80 long and 1,60 meters deep. The maximum height covered is 2,10 meters and it is chosen according to the height of the athletes. The used protocol is SAFLO. After marker positioning on the landmarks and the measure of antropometrical parameter, begins the acquisition of six walk.

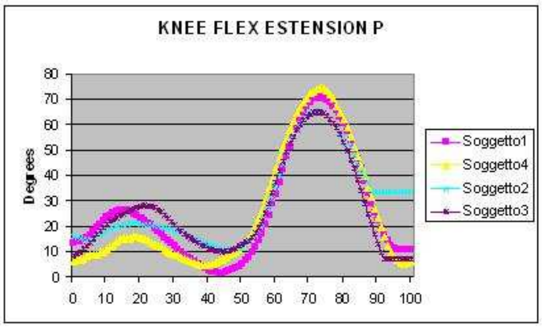
| Parameters | Normal subject | Amputee subject | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ***Subject 1*** | | ***Subject 2*** | | ***Subject 3*** | | ***Subject 4*** | |
| Cadence (step/min) | 110 ± 10 | 123 | | 106 | | 112 | | 111 | |
| Velocità (m/sec) | 1,3 | 1,53 | | 1,2 | | 1,47 | | 1,25 | |
| | | Prosth. | Sound limb | Prosth. | Sound limb | Prosth. | Sound limb | Prosth. | Sound limb |
| Stance ( %) | 62 | 63 | 60 | 63 | 64 | 62 | 61 | 61 | 64 |
| Swing (%) | 38 | 37 | 40 | 37 | 36 | 38 | 39 | 39 | 36 |
| Stride lenght (mm) | 1350 | 1468 | 1510 | 1374 | 1363 | 1559 | 1601 | 1366 | 1349 |
| Stride time (ms) | 1000±100 | 966 | 972 | 1100 | 1165 | 1089 | 1055 | 1072 | 1078 |

## RESULTS




## DISCUSSION

The activity examines the kinematic and kinetic of these joints: pelvic, hip, knee and ankle. The Range of Motion of pelvic tilt is proportional to the subject energetic consumption: for amputees is higher than normal subject. The hip and knee extension are limited in toe off and lower peak flexion then normal subject.

## CONCLUSION

The asymmetry, between the prosthetic and the sound limb, is really remarkable. The compensatory mechanisms of sound limb underlines the different kinematics of prosthetic limb. The ankle rotation of the sound limb plays as a rule . A weak dorsiflexion appears at the beginning of the stance phase for the prosthetic ankle due to the foot elasticity and shape; the nearly horizontal feature during the swing phase is due to foot stiffness and its morphology creates a remarkable plantar flexion.

## REFERENCES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