DEVELOPMENT OF ANKLE ORTHOSIS FOR ANKLE INJURY PREVENTION

Submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons.)

By

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirement for the degree of Bachelor of Manufacturing Engineering. The members of the supervisory committee are as follow:

……

(Principal Supervisor)

En.Tajul Ariffin bin Abdullah

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ABSTRAK

Ortosis pergelangan kaki adalah sokongan luar dan menghalang pelbagai kecederaan kaki dan pergelangan kaki. Tujuan laporan ini adalah untuk merancang orthosis pergelangan kaki dengan pengimbas 3D dan proses pembuatan tambahan.Matlamat projek ini menghasilkan orthosis pergelangan kaki dengan meningkatkan fungsi dan selesa kepada pengguna. Projek ini memberi tumpuan kepada reka bentuk dan pembangunan prototaip ortosis pergelangan kaki berdasarkan geometri bentuk kaki pengguna. Kebanyakannya, peranti sokongan yang sedia ada untuk orthosis terutama bagi pengguna yang mengalami kecederaan yang teruk seperti 'ankle sprain'. Ia adalah kecederaan muskuloskeletal yang paling biasa untuk atlet. Fungsi ortosis pergelangan kaki disesuaikan untuk saiz pengguna yang sesuai, saiz kasut, selesa, mudah dipakai. Di samping itu, kos yang diperlukan untuk menghasilkan sokongan buku lali yang sedia ada agak mahal kerana mereka memerlukan lebih daripada satu mesin proses dan bahan untuk menghasilkan orthosis pergelangan kaki. Dalam projek ini, terdapat beberapa kaedah yang telah digunakan untuk menyelesaikan perkembangan proses ortosis pergelangan kaki. Sebagai permulaan, tinjauan awal telah dijalankan untuk mendapatkan maklum balas daripada pengguna bagi memilih konsep saiz yang sesuai daripada saiz standard untuk orthosis. Selain itu, AHP di gunakan untuk memilih keperluan reka bentuk terbaik daripada tiga reka bentuk konsep yang berbeza. Setelah memperoleh data, pengimbas 3D digunakan untuk mengimbas kaki dan mengubahnya menjadi 3D data dengan perisian studio Geomagic 10. Kemudian, data kaki di edit dan di periksa menggunakan perisisan Materialise Magics. Manakala ortosis buku lali dilukis dan diedit oleh perisisan Meshmixer. FEA di gunakan untuk menguji analisis tekanan untuk menilai kekuatan ortosis buku lali yang baru dengan menggunakan perisian Solidworks. Filamen TPU dipilih untuk menghasilkan ortosis pergelangan kaki dengan menggunakan mesin FDM. Akhirnya, ujian fungsian adalah berdasarkan pengujian ke atas manusia.

ABSTRACT

Ankle orthosis is external support and prevent the various foot and ankle injury. The purpose of this report is to design an ankle orthosis with 3D scanner and additive manufacturing process. The aims of this project is produce the ankle orthosis with improve functionality and comfortably to a user. This project focused to design and develop a prototype of ankle orthosis based on geometry of user's foot shape. Mostly, the existing support device for ankle orthosis especially for users that suffers from severe injuries such as ankle sprain. Ankle Sprain is the most typical musculoskeletal injury for athletes. The function of ankle orthosis is adjusted for the appropriate size of user, size into shoes, comfortable, easy to wear. In addition, the cost required to produce an existing ankle support is quite expensive as they require more than one process machine and material to produce ankle orthosis. To finish the process development of the ankle orthosis there are several methods had been used for conducting this project. As starting, a preliminary survey was been conducted to get feedback from the user about the respondents were been choose for customize size concept than standard size for the ankle orthosis. Besides that, Analytical Hierarchy Process is used to select the best design requirement from three different concept design. After obtain the data, the Faro Scanner Freestyle 3D is used to scan the foot and convert it into the software Geomagic studio 10. Then, edit and check the foot data using Materialise Magic software. Meanwhile the ankle orthosis is drawn and edited by Meshmixer software. By using Solidwork software (FEA) for evaluate the stress analysis of the strength of new ankle orthosis. The filament of TPU was selected for fabricate ankle orthosis by using FDM machine. Lastly, the functional test was conducted based on human subject testing.

DEDICATION

I would like to dedicate this work to my

Beloved parents

Dearest siblings

Honorable supervisors and lecturers

Supportive friends and mates

For giving me moral support, money, cooperation, encouragement and also understandings,

Thank You So Much & Love You All Forever

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LIST OF ABBREVIATIONS

3D	-	3 Dimensional
ABS	-	Acrylonitrile Butadiene Styrene
AHP	-	Analytical Hierarchy Process
AFO	-	Ankle Foot Orthosis
AM	-	Additive manufacturing
ATFL	-	Anterior Talofibular Ligament
CAD	-	Computer aided design
CFL	-	Calcaneofinular Ligament
DM	-	Decision Maker
DLP	-	Digital Light Processing
EBM	-	Electron beam melting
FDM	-	Fused deposition modeling
FEA	-	Finite element analysis
FKP	-	Faculty of Manufacturing Engineering
FO	-	Foot Orthosis
FOS	-	Factor of Safety
LED	-	Light-Emitting Diode
LOM	-	Laminated Objective Manufacturing
PA	-	Polyamide
PC	-	Polycarbonate
PETG	-	Polyethylene Terephthalate
PLA	-	PolyLactic Acid
PTFL	-	Posterior Talofibular Ligament
SLA	-	Stereolithography
SLM	-	Selective laser melting
SLS	-	Selective laser sintering

STJ	-	Subtalar Joint
STL	-	Stereolithography
TCJ	-	Talocrural Joint
TPU	-	Thermoplastics Polyurethane
UV	-	Ultraviolet

LIST OF SYMBOLS

° C	-	Degree Celsius
°	-	Degree
α	-	Alpha
%	-	Percentage
&	-	And
J/kg° C	-	Joule per kilogram degree Celsius
MPa	-	Mega Pascal
kg	-	Kilogram
W	-	Eigenvalue or Priority vector
m	-	Meter
mm	-	Millimeter
CI	-	Consistency Index
CR	-	Consistent Ratio

CHAPTER 1
INTRODUCTION

This chapter describes the background of the study, the problem statement, objective, and scope of the study.

1.1 Background of the study

Ankle Sprain is the most typical musculoskeletal injury for athletes. The highest rate of ankle injury occurs due to sport require cutting movement, sudden stops such as soccer and basketball. In United State, every year has 6.5million student who joins the supervised basketball and soccer competition, 15% of these athletes suffer ankle sprains (McGuine and Keene, 2006). The ankle is one of the important body parts to support most person weight when standing. The ankle is combined with three bone which is tibia, fibula, and talus. The ligaments are joint these bones and allow ankle movement. One of these parts damaged will be temporarily lost to walk. There are many methods to protect and prevent ankles such as High-top shoes, tape the ankle, orthoses or several mixtures of these way. Most of investigate show that properly applied tape, orthosis, brace have good performance (Thacker et al., 1999). A study from the US, the number of athletes use orthosis, 2.6 sprains more effective as compared to tape, 4.9 sprains (McGuine and Keene, 2006). Orthosis is an outside sustain, may improve proprioception, inexpensive as well as protect accidentally injured.

Nowadays, additive manufacturing has become very popular in many fields such as automotive industry, aerospace, architecture, consumer products and healthcare. Additive manufacturing was increased layer by layer process for the produce three dimensional part with CAD models. This provides the benefit of building parts with material and geometric complexities can hardly be produced by reducing manufacturing. Additive manufacturing is known as 3d printing, less material waste, mass customization and faster of processing time as compared to traditional method (Walbran et al., 2016). There are many different kinds of 3d printing, which is fused deposition modelling (FDM), Stereolithography (SLA), Digital Light Processing (DLP), Electronic Beam Melting (EBM) and selective laser melting (SLM) and Laminated objected manufacturing (LOM). These processes can be used many different kinds of material acrylonitrile-butadiene-styrene (ABS), metal, polymer powder, adhesive coated powders, the photo-curable resin, polyamide, wax, etc. (Guo and Leu, 2013). In this project, ankle orthosis will produce by using Fused Deposition Modelling (FDM). Fused Deposition Modelling is a process which in the rapid prototyping and additive manufacturing for creating the prototype 3D product respectively.

In addition, a new approach to the design and manufacture of customized foot orthoses through digital techniques such as usually based on 3D modelling, 3D scanner and 3D printing has been reported as an effective alternative to overcoming the limited of the traditional method. The first method was digitized the user's foot with a 3D laser scanner device and use a 3D system to design orthosis (Ciobanu and Soydan, 2012). The last step was used FDM for the manufactured, assembled and tested. The purpose of this project is to develop and design ankle orthosis that can protect people injury from any sports activities and exercise. Ankle orthosis is a simple and inexpensive device to support a body segment, to protect ankle injury and help motion to improve body function. Analytical Hierarchy Process (AHP) is a method of multi-criteria decision, was established by Saaty in 1976. (Koç and Burhan, 2015). AHP is applied to obtain the best selection of product criteria.

The purpose of the project is to study the ankle anatomy, survey relate to ankle orthosis, the methods of 3D scanner that relates to design of individual ankle orthosis and 3D printing for fabricating the ankle orthosis.

1.2 Problem Statement

The ankle sprain is the most common kind of injury that let an athlete or a runner failed during the competition, however, injuries of overuse such as stress fractures, tendonitis, and heel pain. One of the ankle injury problems is repeated motion. Most athletes need to repeat the same action, such as running, kicking, cutting and swinging. During reparative motion, the ankle and foot cannot keep pace with the work at the same time it will occur ankle sprain. In addition, when athletes need to prepare for the competitive, it is impossible to avoid overtraining and practices.

The second problem is ankle and foot suddenly twist and sprain during sports activity and exercise whether jogging, running, walking, play badminton as well as dancing. This is due to external factor include uneven surface, landing surface, tripping on a hole in the ground, stepping off a curb wrong. According to a study published in Hopkinson and Andrew, the ankle injuries over than 75 percentage are lateral ankle sprains (Nuhmani and Khan 2013).

On the other hand, one of the reasons for the ankle injury is an internal factor such as wearing inappropriate footwear, foot flexibility, gender and personal weight. Therefore, many medical doctors always encourage all athletes must wear ankle orthosis, ankle brace or taping during sport and exercise. Unfortunately, several athletes do not like to wear orthosis, ankle brace or taping because sometimes need to constantly adjust the size of ankle support to continue walking correctly, short of durability and feel uncomfortable. One of the uncomfortable reason is the poor material of ankle orthosis affect the user encounters extreme heating and sweating problem during long period usage (Ayodeji Emmanuel Oke and Raphiri, 2015). Ankle orthosis is an outside protect the foot and ankle and it may be difficult to fit inside the shoe.

1.3 Objective

The objective of this research are:

1. To identify the problems of current ankle orthosis and injuries related to the ankle area.
2. To design and develop a new ankle orthosis that will improve the comfort, ease to use, light weight and adjustability for ankle injury prevention using additive manufacturing.
3. To test and validate the design of ankle orthosis.

1.4 Scope

This research is focused on developing and designing ankle orthosis for basketball player of FKP UTeM. Ankle orthosis can protect the ankle during daily wear and sport to allow repetitive any action such as running, kicking and swinging. In order to develop a new ankle orthosis, one of the main tool is used three-dimensional scanner to scan the foot of the user. Then, the data will be used for designing, analyzing and testing the ankle orthosis. All 3D modelling of ankle orthosis will be designed using Magic and Meshmixer software. There are two methods to select the best design requirement for ankle orthosis which is questionnaire and AHP. The material used to fabricate the ankle orthosis is Thermoplastic polyurethane (TPU). The ankle orthosis prototype will be fabricated using the Fused Deposition Modelling machine (FDM).

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction of Literature Review

In this chapter, related information of the project is summarized. The literature review includes the introduction to ankle orthosis, relevant anatomy, 3D scanner, Additive manufacturing, Fused Deposition Machine and material selection for ankle orthosis, exiting product (patent) and method selection for design the ankle orthosis and to analysis it. The sources are from journals, book, internal and others the guide to completing this project.

2.2 Orthosis

An orthosis is an outside sustain, may improve proprioception, inexpensive as well as protect accidentally injured. The orthosis can prevent the various foot and ankle injury such as ankle sprains, heel pain, excessive pronation and under-pronation. Excessive pronation is known as over-pronation that causes by subtalar eversion (calcaneal valgus). This is due to complex movement such as calcaneal eversion, foreleg abduction, and dorsiflexion. As a result, one has a tendency to walk on the inner border of the foot (Kirby, 2002). While under-pronation is known as supination. Under-pronation exhibits inversion, adduction, and plantar flexion so that one has a tendency to walk on the outer border of the foot (Ciobanu and Soydan, 2012b).

2.3 Relevant Anatomy

An ankle is one of the important body part to support most person weight when standing. The ankle and foot consists of 26 separate bones of the foot and long bones of the lower limbs to become a total of 33 joints (Brockett and Chapman, 2016). The ankle is build up by connecting the talus, tibia and fibula as in Figure 2.1. It also joint the lower leg to the foot. There are contain two part of joints which the talocrural joint (TCJ) and the subtalar joint (STJ) as shown in Figure 2.3. The articulation of the back side of the fibula and tibia with the talus are composed of TCJ. The distal part of the fibula is included inside a perpendicularly oriented groove, the fibula notch, positioned on the lateral sides of the tibia and located between the front and back tibia tubercles. The distal part of the tibia and fibula become a guard housing that encloses and articulates with the superior part of the talus and trochlea body (Dubin et al., 2011).

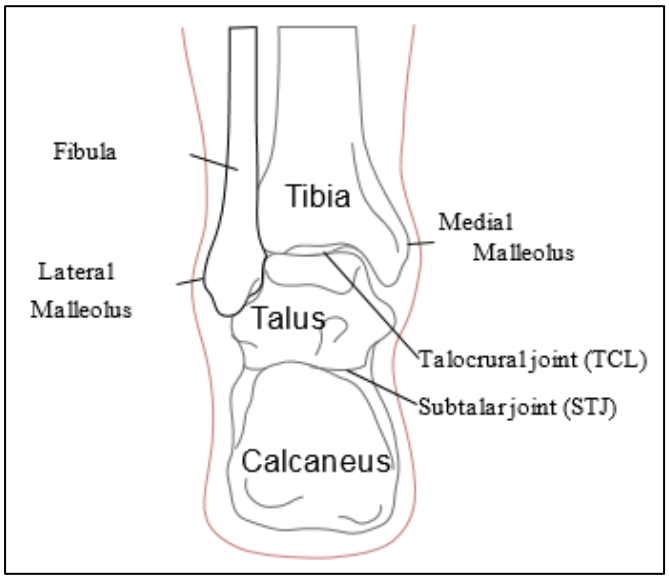

Figure 2.1: The ankle, which is a junction of the talus, the tibia, and the fibula. Also labelled are the fibula, tibia, anterior tibia tubercle, medial malleolus, lateral malleolus, and talus.

The housing in medial boundary contains of the medial malleolus, the distal part of the tibia. While the superior boundary includes of the Pilon a transverse extension of the tibia. However, the lateral boundary involves of the lateral malleolus, the distal part of the fibula. During the step, motion area of TCJ contains of ground responsive dorsiflexion when the tibia moves forward over the foot; and plantar flexion, the heel rising from the ground as