UNIVERSITI TEKNIKAL MALAYSIA MELAKA

PRODUCT DESIGN AND ANALYSIS OF BIO-INSPIRED 3D PRINTED WRIST SPLINT FOR REHABILITATION

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A thesis submitted
in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled “Product Design and Analysis of Bio-inspired 3D Printed Wrist Splint for Rehabilitation” is the result of my own study except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

Name : Nur Wardah Sufina binti Padzil

Date : 28/01/2022

APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the Bachelor of Manufacturing Engineering Technology with Honours.

Signature .....

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DEDICATION

Every challenging work needs self-efforts as well as guidance from elders especially those who are very close to my heart.

Special thanks and my humble effort to my sweet and loving family especially parents, parents-in-law, husband, son, and siblings.

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ABSTRACT

A wrist splint is a rehabilitation device to keep the wounded portion of the hand in place and protect it from additional harm. For the past few decades, a plethora of splints have been developed for maximum wrist immobility to treat fractured bones around the wrist and thumb for rehabilitation, as well as to function as versatile tools to help the movement of damaged parts with some assistance. However, the use of conventional immobilization splints can cause a lot of mishaps and discomfort to the patients which contribute to poor aesthetics, fit, and performance. To overcome this, the use of additive manufacturing (AM) offers many benefits including functional, ergonomic, user-fit, and aesthetic improvements which collectively can contribute to an improved emotional response to a developed and fabricated personalized splint. By exploring AM technology, a highly complex geometrical wrist splint embedded of bio-inspired design can be designed and analyzed with the combination of 3D Computer-Aided Design (CAD) software, Meshmixer, and Solidworks. Finite Element Analysis (FEA) is used to simulate the behavior part of a part under a given condition. This is important to predict failure of the splint structure or material under an unknown condition.

ABSTRAK

"Wrist splint" ialah alat pemulihan untuk mengekalkan struktur bahagian tangan yang cedera pada tempatnya dan melindunginya daripada bahaya tambahan. Sejak beberapa dekad yang lalu, terdapat pelbagai jenis "wrist splint" telah dibangunkan untuk ketidakmobilan maksimum pada pergelangan tangan bagi merawat tulang patah di sekitar pergelangan tangan dan ibu jari untuk pemulihan, serta berfungsi sebagai alat serba boleh untuk membantu pergerakan bahagian yang luka dengan bantuan tambahan. Walau bagaimanapun, penggunaan pendakap imobilisasi konvensional boleh menyebabkan banyak kecederaan dan ketidakselesaan kepada pengguna yang menyumbang kepada nilai asthetik, kecergasan dan fungsi yang lemah. Untuk mengatasinya, penggunaan pembuatan tambahan menawarkan banyak faedah termasuk penambahbaikan fungsi, ergonomik, kesesuaian pengguna dan nilai estetik yang secara kolektif boleh menyumbang kepada tindak balas emosi yang lebih baik kepada pendakap peribadi yang dibangunkan. Dengan meneroka teknologi pembuatan tambahan, pendakap pergelangan tangan yang mempunya geometri kompleks tinggi yang dilhamkan oleh reka bentuk semula jadi serta dianalisis dengan gabungan perisian Reka Bentuk Bantuan Komputer (CAD) 3D, Meshmixer dan Solidworks. Analisis Elemen Terhingga (FEA) digunakan untuk mensimulasikan bahagian tingkah laku bahagian di bawah keadaan tertentu. Ini penting untuk meramalkan kegagalan struktur pendakap atau bahan dalam keadaan tekanan asing.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

AM	-	Additive Manufacturing
3D	-	Three-Dimensional
CAD	-	Computer-Aided Design
SLS	-	Selective Laser Sintering
ADL	-	Activity of Daily Living
2D	-	Two-Dimensional
STL	-	Certificate Trust List
RE	-	Reverse Engineering
CAE	-	Computer-Aided Engineering
CMC	-	Carpometacarpal
IP	-	Interphalangeal
MCP	-	Metacarpophalangeal
DIP	-	Distal Interphalangeal
PIP	-	Proximal Interphalangeal
FDM	-	Fused Deposition Modelling
FEA	-	Finite Element Analysis
MAW	-	Maximum Acceptable Weight
kg	-	Kilogram
mm	-	Millimeter
N	-	Newton

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

This chapter will explain and clarify the background of the project, its characteristics, and the improvement that needed to be achieved. This research is on an idea that has been composed of fundamental theory from previous researchers, journals, books, and online sources. Therefore, the informative issues collected are intended to identify the improvements needed to complete this research.

1.1 Project Background

For almost a decade, additive manufacturing (AM), often known as 3D printing, has been employed in medical applications (Mihalko, 2019). AM is the process of layer by layer converting a virtual 3D representation of an item into a physical object. (Acuk, 2014).

In addition, 3D printing, also known as rapid prototyping is a process of layering items utilizing three-dimensional software planning and material deposition techniques to create objects layer by layer. Traditional manufacturing processes like grinding and milling, on the other hand, are subtractive, meaning they rely on removing material to create a final product (Saptarshi & Zhou, 2019).

Rapid prototyping of computer-generated information via three-dimensional (3D) printing is a well-established idea in the manufacturing business, one created in 1983 (Jastifer & Gustafson, 2019).

Despite the fact that additive manufacturing and 3D printing technology have been around since the 1980s, their use in orthopedics has recently reached a tipping point. A number of variables have ushered in a fascinating new era in manufacturing, one that places

greater power in the hands of the creator and more personalisation in the hands of the end-user. Orthopedics has long been a hands-on profession. Surgeons are frequently tasked with reimagining and reshaping anatomy. In this regard, 3D printing technologies may have finally found their ideal medical specialization in orthopedics (DiPaola & Wodajo, 2019).

1.2 Problem Statement

One of the most vital components of the human body is the hand. This is required for practically all day-to-day tasks. It allows humans to change their environment while engaging with objects around them, such as gripping with a given force, doing complex actions like playing an instrument, and, most significantly, touching and feeling (Tecnológico & Rica, 2014).

Patients may have several complications and discomfort when using traditional immobilization splints (Blaya et al., 2019). The current designs of wrist splints contribute to poor aesthetics, fit, and performance. The current design is a too medical look which would affect the patient's psychology. Thus this research plans to redesign the physical look to have more aesthetic value thus, by using 3D printing with high geometric complexity in an attempt to overcome these issues. Additive manufacturing (AM) has a number of advantages, including increased functionality, ergonomics, user-fit, and aesthetics, all of which can lead to a better emotional reaction to a customized splint (Acuk, 2014).

Equally important, the existing products that are focused on relating to medical devices used for a wrist splint to help maintain a hand in a whole size which means the splints also need to be put on the area that is not needed. Therefore, the idea of designing a detachable concept that divided one splint into three parts to have multipurpose performance.

As a result, the goal of this study is to create hand support that will aid scanning patients who require customized therapy for fractured bones to preserve appropriate

alignment. The support keeps the hand in a stable posture that's appropriate for the patient's level of muscle tonicity and should not get in the way of continuous therapy.

1.3 Research Objective

The purpose of this design is to innovate a wrist splint with better features by prioritizing the design elements needed in a product to produce a high-quality wrist splint. Hence, the main objective of the research study are as follows:

a) To design and analyse a high geometrical complex wrist splint using the combination of 3D Computer-Aided Design (CAD) software Solidworks and Meshmixer.

b) To develop and fabricate wrist splint using laser sintering technique in Additive Manufacturing (AM).

1.4 Scope of Research

Up to this point, 3D printing in hand and wrist rehabilitation has primarily been limited to feasibility studies and case series. The lack of specialized scanning applications, difficult digital design tools, and time-consuming and error-prone printing processes are just a few of the factors. (Keller et al., 2021a).

AM is a proven feasible approach for the design and production of personalized body-fitting goods because it can account for functional, environmental, ergonomic, aesthetic, emotional, and user fit needs (Paterson et al., 2015).

CHAPTER 2

LITERATURE REVIEW

This chapter provides an introduction of the project background including protective masks in medical applications and Additive Manufacturing (AM). The background study, objectives, and the scopes of this project on the development of wrist splint by using a 3D printer will be introduced.

2.1 Wrist Splint

For the past few decades, a plethora of splints has been developed for maximum wrist immobility to treat broken or fractured bones around the wrist and thumb for rehabilitation, as well as to function as versatile tools to help the movement of damaged parts with some assistance. Orthotics can help with biological alignment, deformity correction, injury prevention, pain relief, increased mobility, and independence.(Kurtz et al., 2017).

A splint is a stiff or flexible device that keeps a displaced or moveable part in place, as well as keeping a wounded portion in place and protecting it from additional harm. Splints for the wrist are used for a myriad of purposes. Patients with wrist fractures or long-term diseases like osteo or rheumatoid arthritis, as well as those who require post-surgical treatments to aid in their rehabilitation, may benefit from splints (Kelly et al., 2015).

A wrist splint assembly that can be custom-fit to a supported hand and wrist. A first splint for positioning against and forming to the volar aspect of the hand and wrist, and a second splint for positioning against and forming to the dorsal aspect of the hand and wrist, comprise the wrist splint assembly (D.Dayton, 2011).

Moreover, a splint device is used to immobilize the target anatomy in contemporary clinical practice. Plaster of Paris is commonly used to immobilize patients, although it may

be quite restricting and painful for them. Splints can be either a pre-made “off the shelf” model or a bespoke gadget constructed of thermoplastic material (Mohammed & Fay, 2020).

Regardless of the method of attachment, to maintain the hand aligned properly and offer resistance to the forces generated by the finger motion mechanism, a wrist or thumb brace may be required. A brace can act as a mounting point for the device or its components to assist the user's hand and arm (Kurtz et al., 2017)

The main aim of these devices is to restore unaided functionality over time or to restore all previously lost capability at some point. A functional orthosis device aims to increase an individual's capacity to accomplish daily chores. While the device may aid in the enhancement of long-term independent function, it is designed to make the activity of daily living (ADLs) easier and more convenient for the user (Kurtz et al., 2017).

Accordingly, the possibilities in upper extremity splinting for enhanced fit, functionality, and aesthetics, attributable to AM systems and existing work into custom-fitted devices. A 'best fit first-time' strategy to offering a personalized fit for a patient based on their anatomy and rehabilitative demands was found to be potentially advantageous (Paterson et al., 2015).

2.1.1 Type of Wrist Splint

There are two main categories of splints; prefabricated ‘off-the-shelf’ splints and custom-made splints (Paterson et al., 2015).

I. prefabricated ‘off-the-shelf’ splints

- Prefabricated splints can be purchased in several places, including pharmacies, but they can also be prescribed by splinting specialists like occupational therapists or physiotherapists.

- Prefabricated splints may be available in a variety of sizes (e.g. small, medium, and large), implying a "one size fits all" approach, and are not necessarily personalized to an individual until modified by the user or a splinting professional.
- As a result, off-the-shelf splints will never be able to fit every patient thus necessitating the use of custom-made splints.

II. custom-made splints

- custom-made splints are produced and distributed exclusively by splinting experts to fit individual lifestyles, as well as anatomical needs of their condition.
- Custom-made splints provide better fit and comfort, and in many cases are less bulky than store-bought alternatives.
- Splints can also be custom-made to suit variations of size and deformity, which is not always achievable with off-the-shelf products, which unavoidably have restrictions on adjustability.
- Custom-made splints keep their form at all times, but off-the-shelf products must be adjusted every moment they are used, which is not always feasible to repeat the modification perfectly each time.

2.1.2 Activities That Lead to Wrist Injuries

I. Sports participation

- Wrist injuries are common in a variety of sports, including those that require impact and those that require repetitive wrist stress. Football, bowling, golf, gymnastics, skiing, and tennis are mostly just a few examples.

II. Repetitive work

- Virtually every action requires the use of your hands and wrists. When done repeatedly and with enough force, it can cause crippling wrist discomfort.

III. Certain disease or condition

- Carpal tunnel syndrome can be exacerbated by pregnancy, diabetes, obesity, rheumatoid arthritis, and gout.

IV. Sudden impacts

- When you fall forward onto your outstretched hand, you are more likely to sustain a wrist injury. Sprains, strains, and even fractures can result from this. A scaphoid fracture is a wrist fracture that affects the thumb side of the wrist. This sort of fracture may not be visible on X-rays right after the accident.

2.2 Rehabilitation Definition

Based on Oxford Dictionary, rehabilitation means the action of restoring someone to a healthy or normal life through training and therapy after imprisonment, addiction, or illness (Chakraborty et al., 2021). Hand injuries are among the most common injuries sustained by athletes. Unfortunately, there is a tendency to minimize their severity as the hand does not bear weight and the injuries rarely render the athlete unable to compete (Alexy & De Carlo, 1998).

In addition, rehabilitation is a goal-oriented, time-limited procedure aimed at restoring a functionally damaged individual's psychological, physical, and social functions to their normal levels. (Dionyssiotis et al., 2008)

Besides that, the decision which is executed is usually made by healthcare professionals (Mohammed & Fay, 2020). To recover lost function or increase muscular performance over time, rehabilitation devices are frequently utilized in conjunction with a therapist (Kurtz et al., 2017).