ANTHROPOMETRY STUDY OF KNEE AND CORRELATION TO THE SIZING OF TOTAL KNEE ARTHROPLASTY IN MALAY POPULATION

DR. LEONG JIAHOUR

DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE MASTER OF MEDICINE (ORTHOPAEDICS)

UNIVERSITI SAINS MALAYSIA

2022

ANTHROPOMETRY STUDY OF KNEE AND CORRELATION TO THE SIZING OF TOTAL KNEE ARTHROPLASTY IN MALAY POPULATION

ACKNOWLEDGEMENTS

In preparation of my thesis, I had the guidance and help from few respected persons, who deserve my deepest gratitude. As the completion of this thesis gave me much pleasure, I would like to show my gratitude to my supervisor, Dr. Emil Fazliq Mohd, he has been a dedicated mentor that guides me through my study and writing the thesis. I appreciate all the full effort, kind patience and precious time that he spends with me and for providing insight and expertise that greatly improved the manuscript. I would also like to thank my co-supervisor, Dr. Ahmad Tarmizi Bin Musa for giving me a good guidance for thesis throughout numerous consultations.

Finally, I must express my very profound gratitude to my parents and to my supportive wife and closes friends for providing me with unfailing support and continuous encouragement throughout my years of study and through the process of researching and writing this thesis. This accomplishment would not have been possible without them. Thank you.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

aTEA	Anatomical Trans Epicondylar Axis
AP	Anteroposterior
CT	Computed Topography
CTA	Condylar Twist Angle
fAP	Femoral Anteroposterior dimension
fAR	Femoral Aspect ratio
fML	Femoral Mediolateral dimension
HUSM	Hospital Universiti Sains Malaysia
JEPeM	Jawatankuasa Etika Penyelidikan Manusia
ML	Mediolateral
PACS-UV	Picture Archiving and Communication System Centricity Universal Viewer
PCL	Posterior Condylar Line
sTEA	Surgical Trans Epicondylar Axis
tAP	Tibial Anteroposterior dimension
tAR	Tibial Aspect ratio
TEA	Trans Epicondylar Axis
TKA	Total Knee Arthroplasty

tML	Tibial Mediolateral dimension
USM	Universiti Sains Malaysia

ABSTRAK

Latar Belakang:

Kedudukan implan penukaran sendi lutut palsu (TKA) yang tepat dan sesuai dengan pemotongan tulang adalah faktor penting untuk prognosis yang baik kepada TKA. Saiz dan rekabentuk implan TKA semasa berdasarkan morfometri lutut orang Kaukasia. Kami percaya terdapat perbezaan saiz di antara implan TKA semasa dengan saiz lutut orang Melayu yang menyebabkan pemasangan implan tidak optimum dan seterusnya memberikan hasil yang kurang memuaskan. Objektif kajian ini adalah untuk menganalisa pemotongan simulasi femur dan tibia bagi populasi Melayu dan korelasinya dengan implan TKA semasa.

Kaedah:

Pengukuran antropometri radiologi 139 lutut (44 lelaki dan 33 wanita) diukur dari rekod imbasan topografi berkomputer(CT) bagi semua pesakit berbangsa Melayu yang menjalani imbasan CT bahagian anggota bawah di Hospital Universiti Sains Malaysia (HUSM) dari Januari 2017 hingga Disember 2020. Data tersebut merangkumi dimensi anterior-posterior femur (fAP), dimensi medial-lateral femur (fML), dimensi anterior-posterior tibia (tAP), dimensi medial-lateral tibia (tML) dan sudut putaran condylar (CTA). Nisbah aspek juga dihitung, dan data-data ini dibandingkan dengan 2 sistem implan TKA semasa di HUSM iaitu Stryker dan Amplitude.

Keputusan:

Nilai min fAP adalah 52.3mm (SP 3.12) dan 48.5mm (SP 2.50) untuk lelaki dan wanita, manakala nilai min fML adalah 72.7mm (SP 3.12) dan 63.4mm (SP 3.12). Nilai min tAP adalah

49.1mm (SP 2.60) dan 43.9mm (SP 2.53) untuk lelaki dan wanita, manakala nilai min tML adalah 74.6mm (SP 3.64) dan 65.3mm (SP 2.89). Nilai min CTA adalah 5.2 ° (SP 1.94) dan 4.6 ° (SP 2.21) untuk lelaki dan wanita.

Kedua-dua implan TKA yang dikaji mempunyai dimensi fML yang lebih besar berbanding dengan pemotongan simulasi femur untuk dimensi fAP tertentu.

Kesimpulan:

Implan TKA yang dinilai dalam kajian ini tidak optimum untuk lutut Melayu yang lebih ketara bagi komponen femur untuk perempuan. Implan penukaran sendi lutut palsu yang dinilai perlu diubahsuai agar lebih sesuai dengan populasi Melayu, terutamanya komponen femur. Hasil dari kajian ini dapat memberikan data asas yang diperlukan untuk reka bentuk implan TKA yang lebih sesuai dengan populasi Melayu.

Kata kunci:

Antropometri, Lutut, Penukaran Sendi Lutut Palsu, Tomografi Berkomputer, Melayu.

ABSTRACT

Background:

The accurate position and well fit total knee arthroplasty (TKA) implant that match with the resected bone are the important factors to give best outcome for TKA. Currently available TKA implant are based on the morphometry of the Caucasian knee. We believed there is discrepancy in matching current available TKA implant with Malay knees which lead to sub-optimal implant fitting and subsequently a poorer outcome. The objective of this study is to analyze the simulated resected distal femur and proximal tibia of Malay population and correlate to the current TKA implants by using CT scan image.

Methodology:

Radiological anthropometric measurement of 139 knees (44 males and 33 females) was measured from CT imaging record of all Malay patients who underwent CT lower limb in Hospital Universiti Sains Malaysia (HUSM) from January 2017 till December 2020. The data includes femoral anteroposterior (fAP), femoral mediolateral (fML), tibial anteroposterior (tAP), tibial mediolateral (tML) and condylar twist angle (CTA). The femoral and tibial aspect ratio was calculated and correlated to 2 currently used TKA implant systems in HUSM which are the Stryker and the Amplitude.

Results:

The mean fAP values were 52.3mm (SD 3.12) and 48.5mm (SD 2.50) for men and women, while the mean fML values were 72.7mm (SD 3.12) and 63.4mm (SD 3.12). The mean tAP values

were 49.1mm (SD 2.60) and 43.9mm (SD 2.53) for men and women, while the mean tML values were 74.6mm (SD 3.64) and 65.3mm (SD 2.89). The mean CTA value were 5.2° (SD 1.94) and 4.6° (SD 2.21) for men and women.

Both studied TKA implant had larger fML dimension than the resected femur for a given fAP dimension.

Conclusion:

The TKA implant evaluated in present study are not optimal for Malay knees which more profound in distal femur component for female. The TKA implants evaluated need to be adjusted to have a better match with Malay populations, especially femoral component. The result from this study can provide the fundamental data needed for TKA implant design that better fit to Malay Population.

Keywords:

Anthropometry, Knee, Total Knee Arthroplasty, Computed tomography, Malay.

CHAPTER 1: INTRODUCTION

1 INTRODUCTION

Knee joint is a modified hinge joint consist of tibiofemoral joint (articulation of distal femur and proximal tibia) and patellofemoral joint (articulation of distal femur and patella) which allow flexion extension and small amount of rotation. Knee joint can be further divided into three compartment which are medial, lateral, and patellofemoral.

The distal femur has a complex architecture, which also serves as the attachment site of numerous ligaments and tendons. The femoral condyles are asymmetrical in shape and dimension. The distal surface of the medial condyle of the femur is narrower and more curved than that of the lateral condyle. Anteriorly, the condyles are separated by a groove known as the femoral trochlea.

Whereas for proximal tibia, the lateral tibial articular surface is almost circular, the medial is oval with a longer anteroposterior axis, and these differences are reflected in the shapes of the menisci. The larger medial tibial plateau is nearly flat and has a squared off posterior aspect. Both surfaces have a posterior inclination of approximately 7-10 degrees with respect to the shaft of the tibia[1].

Knee joint is susceptible to be affected by various inflammatory and degenerative diseases, ultimately destroying the articular cartilage and affect its proper joint function. Osteoarthritis is the most common pathological disease of knee that affect people with age of 60 and above causing disability that required a total knee arthroplasty (TKA) [2]. However, there were cases in which total knee replacements were performed on the young age group of 60 and below for treatment of rheumatoid arthritis, juvenile rheumatoid arthritis, osteoarthritis

and various other pathology such as posttraumatic arthritis, avascular necrosis, hemochromatosis, lupus, dislocation, sepsis, unstable components, and osteolysis for this age group [3].

Symptoms of knee joint disorders are characterized by pain, joint instability, reduced range of motion, and deformity. There are many treatment options available for pathological disease of the knee, which including operative and nonoperative. Both methods are effective that depend on the patients' situations, characteristics and severity.

Non-operative treatments include pharmacological and non-pharmacological which involved lifestyle modification, weight loss, physiotherapy, muscle strengthening, use of brace, and nonsteroidal anti-inflammatory drugs (NSAIDs). These treatments aim to reduce pain and to delay the course of the disease, however as the disease progress and became more severe, operative management came to play its role.

The options for surgical management include joint preservation and joint sacrificing procedures involving debridement, osteotomy, a partial or a total knee replacement or arthrodesis of the knee. Although the joint-preserving surgeries are less predictable, however when done with appropriate indications, they may afford long term solutions with minimal need for activity restrictions.

Total knee arthroplasty (TKA) requires the use of highly complex surgical techniques, as it involve in accurate placement of well-fitted implants and adequate balancing of the surrounding soft tissues. It has evolved to be a very successful surgery with the ability to reduce pain and disability associated with osteoarthritis and other pathologic knee conditions. To date,

most TKA procedures require resection of one or both cruciate ligaments and loosening of the collateral knee ligaments for proper balancing [4].

Although TKA has been associated with many successes, a revision surgery due to prosthetic damage imposes a much higher cost and more damage. For this purpose, researchers have always sought to find ways to increase the longevity and durability of prosthesis, one of which is the design of prosthesis that are appropriate to the anthropometry of each population as the success rate of TKA largely depends on the choice of prosthesis, the exact size, and the correct location of its components [5].

The maximal coverage of the TKA component on the bone surface can minimizes the stress applied to the bone-implant interface and is essential for a good clinical result and the durability of the replacement

The key factors to a long-term success in total knee arthroplasty are accurate bone cut and appropriate implant size. These aim to achieve the best match between the prosthesis, and the resected bone surfaces. The two variables used to select the femoral implant size are the anteroposterior (AP) length, and the medial-lateral (ML) width. The antero-posterior diameter is important in maintaining flexion-extension spacing and optimal tension in the knee extensor mechanism. The medial-lateral diameter determines adequate coverage of the resected bone surfaces, which allows even stress distribution, tension-free wound closure, and smooth tracking of the patellar component in the trochlear groove during flexion.[6]

Sizing recommendations for TKA seek to maximize the size of the tibial component and minimize the size of the femoral component. The rationale for these recommendations is to have the tibial tray large enough for bony support from the tibial cortex and the femoral component small enough (but without notching the anterior femoral cortex) to avoid over expanding the soft tissue capsular envelope of the knee and extensor mechanism.[7]

The design of TKA protheses were evolved over decades with its design and kinematics led to improved sizing options to more closely duplicate patient anatomy. Proper implant sizing help to avoid complications and maximize outcome. However, most of the TKA prostheses design was according to anthropometric data of Caucasian knee.[8]

Due to paucity of anthropometric data on the knee morphology in Asian population, most of the commercially available TKA prostheses designed that based on anthropometric data of Caucasian knee have been introduced without specific modification which has been suspected as the cause of the component mismatch in Asian people. [9]

It is well known that the Asian population has a smaller distal femoral and proximal tibia size than Western counterpart [10]. Due to the comparatively smaller built and stature of the Asian population, many surgeons believe that commercially available implants, which are mainly designed from the morphometrics gained from the Western population, may not be suitable for Asians.

Mismatch between the prosthesis size and bone may result in severe complications. An undersized component will cause progressive implant migration, which ultimately causes implant loosening [11]. Whilst an oversize component may cause impingement of the

surrounding soft tissues [12]. Therefore, it is importance that an appropriate component size is crucial to produce an optimal performance and long-term success following total knee arthroplasty (TKA).

Rotational alignment is also important for good functional outcome and the long-term success of total knee arthroplasty (TKA). Accurate femoral component rotation is important for normal patellar tracking, symmetrical patellofemoral joint contact, neutral varus-valgus positioning in flexion, and correct rotational alignment of the tibia in extension, and for avoiding anterior femoral notching. Malalignment can cause patellofemoral complications such as subluxation, dislocation, and wear [13].

Excessive external rotation of the femoral component reportedly increases the medial flexion gap and leads to symptomatic flexion instability; external rotation of this component by as little as 5° from the transepicondylar axis (TEA) increases shear forces on the patellar component [14,15]. However, the extent of variability in the femoral alignment that can be tolerated is unclear.

Internal rotation of the femoral component causes a shift into valgus alignment with flexion and increases the quadriceps (Q) angle with deleterious effects on patellar tracking. It also leads to differences in the flexion and extension gaps by altering the relative dimensions of the posterior condyles in flexion. Flexion then causes asymmetrical tension across the prosthesis and gapping on the lateral side. Thus, reproducing this anatomic relationship is important for accurate patellofemoral mechanics after total knee replacement [16].

Most of the anthropometric data of knees are obtained from cadaveric studies, or radiographs of subjects not requiring surgery [17-20]. Osteoarthritic knees are usually deformed, and anatomically different from normal knees. Other morphological measurement methods including three-dimensional computed tomography and manual slide callipers.

Malays are referred to an ethnic group native to the eastern Sumatra, Malay Peninsula, and coastal Borneo, as well as the smaller islands that lie between these locations. This area was collectively known as Malay Archipelago in which in Malay "Nusantara". These locations are today part of the countries of Malaysia, Indonesia, Brunei Darussalam, Singapore and southern part of Thailand.

In Malaysia, Malays are the largest ethnics group in the country which account 50.8% of total Malaysian population of 15.7million in 2015. The Malay subgroups in Malaysia can be broadly classified into 2 main group which are "Anak Jati" the local Malays and "Anak Dagang" the foreign Malays. There is considerable genetic, linguistic, cultural, and social diversity among the many Malay subgroups, mainly due to hundreds of years of immigration and assimilation of various regional ethnicity and tribes.

Hospital Universiti Sains Malaysia (HUSM) is located at Kelantan state in Peninsular Malaysia. The major population in Kelantan is Malay predominantly "Oghe Kelate" Kelantanese Malay. Kelantanese Malay are a sub-ethnic group of Malay native to the state of Kelantan and northern of Terengganu. The Kelantanese Malays are closely related to Thai Malays (especially those in Pattani, Narathiwat, Yala and some parts in Phattalung and Nakhon Si Thammarat provinces) which shared historical, cultural and linguistic as well as origin.

In 1776, Johann Friedrich Blumenbach, a German physician proposed five different types of human races according to his anthropology classification of human skulls. The Tahitian skull type represented Malayan races which generally including all Southeast Asian and Pacific Islanders. The other 4 races described are Caucasian, Mongolian, Ethiopian, and American, which each have a different type of skulls [21]. Over decades, multiple studies have been conducted on knee anatomy on different ethnicity and revealed that presents great variability in different ethnicity [9, 22-27].

The aim of this study is to evaluate morphometrical dimensions of distal femur, proximal tibia and the rotational profile of distal femur amongst young adult Malay population in Malaysia measured using computer tomographic (CT) images datasets. The final derived data will be compared with common available TKA prostheses whether it is proportionally matching to anatomical profiles of the knees. Our intention is to provide morphometric information justifying the production of better fitting implants design for the Malay population in the future.

CHAPTER 2: LITERATURE REVIEW

2 LITERATURE REVIEW

2.1 Overview

Over decades, many studies have been conducted and revealed that knee anatomy presents great variability in gender [11,22, 28-32], ethnicity [9, 22-27], and body types [33].

2.2 Comparison of Knee Dimension in between different gender

Hitt et al., 2003 compared the Anteroposterior / Mediolateral (AP/ML) ratio in 209 female and 128 male knees to the dimensions of six contemporary prosthetic knee systems. For women, they found that with larger sizes of component implant, there having more Mediolateral (ML) overhang. Overhang is a condition in which the implant is beyond the margin resected bone edge. The more ML overhang cause more portion of the implant beyond margin of resected bone exposing the implant with no bone underneath the implant surface. The implication is that past size offerings have been too large on average for women and that this increase would affects the outcomes by over-tightening of the knee capsule causing pain and reduced range of motion [11].

Several studies demonstrate differences in the shape of the distal femur between men and women. For any given anteroposterior (AP) femoral dimension, women tend to have a narrower ML dimension than men. [29,34] Emerson RH et al., 2008 reported that women benefit more than men from the introduction of smaller sizes femoral TKA implant to an existing range of sizes. [7]

2.3 Comparison of Knee Dimension in between different ethnic

A study conducted by Mahfouz et al, 2012 was done to evaluate approximately 1000 Asian, Caucasian, and African American subjects, showed significant differences in the dimensions of the knee not only between sexes but also among the three ethnicities. [35] A study conducted by Otoukesh et al, 2018 evaluated 3-D profile of knee among Asian population, which including Thai, Indian, Japanese (proximal Tibia only), Iranian, Korean, Chinese and Malay (distal femur only) showed that different knee morphometry measurement among different Asian ethnicities, and overall, the knee morphometry is smaller compared to Caucasian population especially for distal femur. [10]

A systematic review done by Kim et al., 2010 also proved the morphologic differences in the distal femur and proximal tibia among and within various ethnicities. For the femur, Caucasian patients had larger femoral AP measurements and smaller aspect ratios than East Asian patients. For the tibia, Caucasian patients had larger tibial aspect ratios than Aethiopian patients.[36]

2.4 Studies from Asian

Anthropometric measurements of the knee joint from many Asian countries are presently available. These include countries like China[37], India[26], Japan[38], Korea[24,39], Taiwan[22], Indonesian[40] and Thailand[23].

Iorio et al.,2007 showed that the Japanese patients had a significantly less postoperative range of motion than caucasian patients. Furthermore, 4.1% Japanese patients required revision after primary posterior cruciate-retaining TKA within an average follow-up of 6.6 years,

whereas only 2.6% of their American cohort needed revision within an average follow-up of 9 years. The authors suggested that the racial knee morphologic differences might be a factor causing the differences in outcome. [41]

Ho et al.,2006 reported that 3 of 5 TKA systems used in China tended to cause mediolateral overhang of the component across the width of the resected femurs of Chinese patients. The authors also found a larger femoral aspect ratio in small knees and a proportionally smaller aspect ratio in large knees, but all the 5 sets of implant systems examined in the study showed little changes in the aspect ratio with AP length. There is a remarkable paucity of information pertaining to clinical outcome differences of TKA across racial groups.[22]

Several studies have compared the morphology of Asian distal femur to femoral component of TKA prostheses currently used in Asia and found that for the femoral aspect ratio (mediolateral [fML]/anteroposterior [fAP]) of these prostheses were not suitable for Asian patients. [22,25,37]

Clinical study has been reported that the anatomical profiles of Asian knees were smaller than those of the Caucasian and has been suggested that the Asian population require smaller range of component size for knee replacement [26].

2.5 Local studies

In Malaysia, there has been limited information regarding knee dimension and studies regarding sizing mismatch. Currently available local studies focused only on distal femur

morphometry [27], [42] and patellar morphometry [43]. Among the 2 local studies which focused only on distal femur, TW Ewe et. al., 2009 [27] compare distal femur morphometry to distal femur TKA implant and Hussain F. et. al., 2013. [42] compare Malay knee morphometry with other Asian ethnicities. There were no local studies which looked at the proximal tibia and rotational profile of the local population.

2.6 Rational of study

From my literature review, there is limited local studies regarding anthropometric study of knee, and the available studies focus only on distal femur and patellar. To the best of our knowledge, there is no published local study regarding the proximal tibia anthropometry.

This study conducted with the aim of establishing a database of normal knee dimension of Malay Population. In addition, this study also aims to find out the possibility of sizing mismatch between knee dimension of Malay Population with current TKA implant available in Malaysia. The morphometric information is useful for justifying the production of better fitting TKA implants design for the Malay population in the future.

2.7 Research questions

1. What are the normal knee dimensions of the adult Malay population in Kelantan?
2. Is there any mismatch in between the knee dimension of the adult Malay population in Kelantan with the size of Total Knee Arthroplasty (TKA) implants available in Kelantan?

CHAPTER 3: OBJECTIVES

3 OBJECTIVES AND HYPOTHESIS

3.1 General Objective

To determine the anthropometric measurement of the knee among the adult Malay population in Kelantan, Malaysia.

3.2 Specific Objective

1) To determine the AP, ML dimensions and the aspect ratio of distal femur among the adult Malay population in Kelantan, Malaysia

2) To determine the AP, ML dimensions and the aspect ratio of proximal tibia among the adult Malay population in Kelantan, Malaysia

3) To determine the condylar twist angle (CTA) of the knee among the adult Malay population in Kelantan, Malaysia

4) To evaluate the compatibility (Match) of TKA implants available in Kelantan, Malaysia.

3.3 Research Hypotheses

1) H_0: The aspect ratio of distal femur(fAR) remained the constant with the change of femoral anteroposterior(fAP) dimension.

   H_1: The aspect ratio of distal femur(fAR) is not constant with the change of femoral anteroposterior(fAP) dimension.

2) H_0: The aspect ratio of proximal Tibia(tAR) remained constant with the change of Tibial anteroposterior(tAP) dimension.

   H_1: The aspect ratio of proximal Tibia (tAR) is not constant with the change of Tibial anteroposterior(tAP) dimension.

3) H_0: The condylar twist angle of the knee of female is larger than that of male

H_1: The condylar twist angle of the knee of female is smaller than that of male

4) H_0: There is no sizing mismatch between the distal femur with the available femoral component of the TKA implants in Kelantan, Malaysia

H_1: There is sizing mismatch between the distal femur with the available femoral component of the TKA implants in Kelantan, Malaysia

5) H_0: There is no sizing mismatch between the proximal tibia with the tibia component of the TKA implants available in Kelantan, Malaysia

H_1: There is sizing mismatch between the proximal tibia with the tibia component of the TKA implants available in Kelantan, Malaysia

CHAPTER 4: STUDY PROPOSAL

SUBMITTED TO ECTHICS

4 STUDY PROPOSAL SUBMITTED TO ECTHICS

4.1 Introduction

Knee joint is a modified hinge joint consist of tibiofemoral joint (articulation of distal femur and proximal tibia) and patellofemoral joint (articulation of distal femur and patella) which allow flexion extension and small amount of rotation. Knee joint can be further divided into three compartment which are medial, lateral, and patellofemoral.

The distal femur has a complex architecture, which also serves as the attachment site of numerous ligaments and tendons. The femoral condyles are asymmetrical in shape and dimension. The distal surface of the medial condyle of the femur is narrower and more curved than that of the lateral condyle. Anteriorly, the condyles are separated by a groove known as the femoral trochlea.

Whereas for proximal tibia, the lateral tibial articular surface is almost circular, the medial is oval with a longer anteroposterior axis, and these differences are reflected in the shapes of the menisci. The larger medial tibial plateau is nearly flat and has a squared off posterior aspect. Both surfaces have a posterior inclination of approximately 7-10 degrees with respect to the shaft of the tibia [1].

Knee joint is susceptible to be affected by various inflammatory and degenerative diseases, ultimately destroying the articular cartilage and affect its proper joint function. Osteoarthritis is the most common pathological disease of knee that affect people with age of 60 and above causing disability that required a total knee arthroplasty (TKA) [2]. However, there were cases in which total knee replacements were performed on the young age group of

60 and below for treatment of rheumatoid arthritis, juvenile rheumatoid arthritis, osteoarthritis and various other pathology such as posttraumatic arthritis, avascular necrosis, hemochromatosis, lupus, dislocation, sepsis, unstable components, and osteolysis for this age group [3].

Symptoms of knee joint disorders are characterized by pain, joint instability, reduced range of motion, and deformity. There are many treatment options available for pathological disease of the knee, which including operative and nonoperative. Both methods are effective that depend on the patients' situations, characteristics and severity.

Non-operative treatments include pharmacological and non-pharmacological which involved lifestyle modification, weight loss, physiotherapy, muscle strengthening, use of brace, and nonsteroidal anti-inflammatory drugs (NSAIDs). These treatments aim to reduce pain and to delay the course of the disease, however as the disease progress and became more severe, operative management came to play its role.

The options for surgical management include joint preservation and joint sacrificing procedures involving debridement, osteotomy, a partial or a total knee replacement or arthrodesis of the knee. Although the joint-preserving surgeries are less predictable, however when done with appropriate indications, they may afford long term solutions with minimal need for activity restrictions.

Total knee arthroplasty (TKA) requires the use of highly complex surgical techniques, as it involve in accurate placement of well-fitted implants and adequate balancing of the surrounding soft tissues. It has evolved to be a very successful surgery with the ability to reduce

pain and disability associated with osteoarthritis and other pathologic knee conditions. To date, most TKA procedures require resection of one or both cruciate ligaments and loosening of the collateral knee ligaments for proper balancing [4].

Although TKA has been associated with many successes, a revision surgery due to prosthetic damage imposes a much higher cost and more damage. For this purpose, researchers have always sought to find ways to increase the longevity and durability of prosthesis, one of which is the design of prosthesis that are appropriate to the anthropometry of each population as the success rate of TKA largely depends on the choice of prosthesis, the exact size, and the correct location of its components [5].

The maximal coverage of the TKA component on the bone surface can minimizes the stress applied to the bone-implant interface and is essential for a good clinical result and the durability of the replacement

The key factors to a long-term success in total knee arthroplasty are accurate bone cut and appropriate implant size. These aim to achieve the best match between the prosthesis, and the resected bone surfaces. The two variables used to select the femoral implant size are the anteroposterior (AP) length, and the medial-lateral (ML) width. The antero-posterior diameter is important in maintaining flexion-extension spacing and optimal tension in the knee extensor mechanism. The medial-lateral diameter determines adequate coverage of the resected bone surfaces, which allows even stress distribution, tension-free wound closure, and smooth tracking of the patellar component in the trochlear groove during flexion.[6]

Sizing recommendations for TKA seek to maximize the size of the tibial component and minimize the size of the femoral component. The rationale for these recommendations is to have the tibial tray large enough for bony support from the tibial cortex and the femoral component small enough (but without notching the anterior femoral cortex) to avoid over expanding the soft tissue capsular envelope of the knee and extensor mechanism.[7]

The design of TKA protheses were evolved over decades with its design and kinematics led to improved sizing options to more closely duplicate patient anatomy. Proper implant sizing help to avoid complications and maximize outcome. However, most of the TKA prostheses design was according to anthropometric data of Caucasian knee.[8]

Due to paucity of anthropometric data on the knee morphology in Asian population, most of the commercially available TKA prostheses designed that based on anthropometric data of Caucasian knee have been introduced without specific modification which has been suspected as the cause of the component mismatch in Asian people. [9]

It is well known that the Asian population has a smaller distal femoral and proximal tibia size than Western counterpart [10]. Due to the comparatively smaller built and stature of the Asian population, many surgeons believe that commercially available implants, which are mainly designed from the morphometrics gained from the Western population, may not be suitable for Asians.

Mismatch between the prosthesis size and bone may result in severe complications. An undersized component will cause progressive implant migration, which ultimately causes implant loosening [11]. Whilst an oversize component may cause impingement of the

surrounding soft tissues [12]. Therefore, it is importance that an appropriate component size is crucial to produce an optimal performance and long-term success following total knee arthroplasty (TKA).

Rotational alignment is also important for good functional outcome and the long-term success of total knee arthroplasty (TKA). Accurate femoral component rotation is important for normal patellar tracking, symmetrical patellofemoral joint contact, neutral varus-valgus positioning in flexion, and correct rotational alignment of the tibia in extension, and for avoiding anterior femoral notching. Malalignment can cause patellofemoral complications such as subluxation, dislocation, and wear [13].

Excessive external rotation of the femoral component reportedly increases the medial flexion gap and leads to symptomatic flexion instability; external rotation of this component by as little as 5° from the transepicondylar axis (TEA) increases shear forces on the patellar component [14,15]. However, the extent of variability in the femoral alignment that can be tolerated is unclear.

Internal rotation of the femoral component causes a shift into valgus alignment with flexion and increases the quadriceps (Q) angle with deleterious effects on patellar tracking. It also leads to differences in the flexion and extension gaps by altering the relative dimensions of the posterior condyles in flexion. Flexion then causes asymmetrical tension across the prosthesis and gapping on the lateral side. Thus, reproducing this anatomic relationship is important for accurate patellofemoral mechanics after total knee replacement [16].

Most of the anthropometric data of knees are obtained from cadaveric studies, or radiographs of subjects not requiring surgery [17-20]. Osteoarthritic knees are usually deformed, and anatomically different from normal knees. Other morphological measurement methods including three-dimensional computed tomography and manual slide callipers.

Malays are referred to an ethnic group native to the eastern Sumatra, Malay Peninsula, and coastal Borneo, as well as the smaller islands that lie between these locations. This area was collectively known as Malay Archipelago in which in Malay "Nusantara". These locations are today part of the countries of Malaysia, Indonesia, Brunei Darussalam, Singapore and southern part of Thailand.

In Malaysia, Malays are the largest ethnics group in the country which account 50.8% of total Malaysian population of 15.7million in 2015. The Malay subgroups in Malaysia can be broadly classified into 2 main group which are "Anak Jati" the local Malays and "Anak Dagang" the foreign Malays. There is considerable genetic, linguistic, cultural, and social diversity among the many Malay subgroups, mainly due to hundreds of years of immigration and assimilation of various regional ethnicity and tribes.

Hospital Universiti Sains Malaysia (HUSM) is located at Kelantan state in Peninsular Malaysia. The major population in Kelantan is Malay predominantly "Oghe Kelate" Kelantanese Malay. Kelantanese Malay are a sub-ethnic group of Malay native to the state of Kelantan and northern of Terengganu. The Kelantanese Malays are closely related to Thai Malays (especially those in Pattani, Narathiwat, Yala and some parts in Phattalung and Nakhon Si Thammarat provinces) which shared historical, cultural and linguistic as well as origin.

In 1776, Johann Friedrich Blumenbach, a German physician proposed five different types of human races according to his anthropology classification of human skulls. The Tahitian skull type represented Malayan races which generally including all Southeast Asian and Pacific Islanders. The other 4 races described are Caucasian, Mongolian, Ethiopian, and American, which each have a different type of skulls [21]. Over decades, multiple studies have been conducted on knee anatomy on different ethnicity and revealed that presents great variability in different ethnicity [9, 22-27].

The aim of this study is to evaluate morphometrical dimensions of distal femur, proximal tibia and the rotational profile of distal femur amongst young adult Malay population in Malaysia measured using computer tomographic (CT) images datasets. The final derived data will be compared with common available TKA prostheses whether it is proportionally matching to anatomical profiles of the knees. Our intention is to provide morphometric information justifying the production of better fitting implants design for the Malay population in the future.