ANTHROPOMETRIC INTRAOPERATIVE MEASUREMENT OF THE PATELLA DIMENSIONS IN TOTAL KNEE ARTHROPLASTY OF FEMALE PATIENTS

DR. NUR SYAHIDA BINTI MOHD TERMIZI

Dissertation Submitted in Partial Fulfillment of the Requirement for the Degree of Master of Medicine

(ORTHOPAEDICS)

UNIVERSITI SAINS MALAYSIA

2018

ACKNOWLEDGEMENTS

It is a great pleasure to express my deep sense of thanks and gratitude to my Supervisor, Dr Shaifuzain Ab Rahman for his timely advice, meticulous scrutiny and scholarly advice to help me accomplish this task.

I would like to express my deepest thanks to all lecturers in Department of Orthopaedics, USM especially Prof. Dr Amran Ahmed Shokri for their involvement in this project as well as my orthopaedic colleagues for their support.

Lastly, I would like to thank my parents for their love and patience.

TABLE OF CONTENTS

		PAGE
TITLE		i
ACKNOWLEDGEMENT		ii
TABLE OF CONTENTS		iii
ABSTRAK (BAHASA MALAYSIA)		v
ABSTRACT (ENGLISH)		vii
CHAPTER 1: INTRODUCTION		
1.1	Introduction	1
CHAPTER 2: OBJECTIVES OF THE STUDY		
2.1	General objectives	7
2.2	Specific objectives	7
CHAPTER 3: MANUSCRIPT		
3.1	Title page	9
3.2	Abstract	10
3.3	Introduction	12
3.4	Methodology	15
3.5	Results	17
3.6	Discussion	20
3.7	Table and figures	25
3.8	References	29
3.9	Guidelines/ Instructions to Authors of selected journal	32

CHAPTER 4: STUDY PRTOCOL **PAGE**

4.1	Study protocol and consent form submitted for ethical approval	36
4.2	Patient information and consent form	54
4.3	Ethical approval letter	67

CHAPTER 5: APPENDICES

5.1	Elaboration of the methodology	72
5.2	Additional tables/graphs	81
5.3	Additional literature review	86
5.4	Additional references	92

ABSTRAK

Pengenalan: Sendi lutut atau ‘patellofemoral’ dianggap sendi yang kompleks, melibatkan tempurung lutut dan bahagian hujung tulang femur atau ‘femoral trochlea’. Radang sendi menyebabkan kehausan pada tulang rawan tempurung lutut yang memerlukan pembedahan gentian sendi lutut. Saiz implan yang betul adalah penting untuk mengelakkan kegagalan implant. Walau bagaimanapun, kebanyakan saiz implan yang digunakan oleh pesakit di Asia dibuat berdasarkan ukuran populasi Barat. Kajian ini dijalankan untuk mendapatkan ukuran anatomi tempurung lutut semasa pembedahan bagi populasi kita dan membandingkannya dengan saiz implan semasa.

Metodologi: Ini adalah sebuah kajian keratan rentas melibatkan pesakit wanita yang menjalani pembedahan gantian sendi lutut di HUSM. Ukuran anatomi tempurung lutut daripada 78 lutut yang diukur semasa pembedahan dikaji. Tempurung lutut diukur menggunakan alat pengukur yang mempunyai ketepatan sehingga 0.5 mm. Ukuran tempurung lutut yang diukur adalah ketinggian, kelebaran, ketebalan dan ukur lilit. Saiz implan terkecil daripada 3 pengeluar turut diukur. Analisis menggunakan ‘descriptive statistics’ dibuat untuk mendapatkan purata ukuran anatomi tempurung lutut sementara ‘Independent T test’ dan ‘One-Way ANOVA test’ digunakan untuk membandingkan ukuran tempurung lutut wanita Malaysia dengan saiz implan semasa.

Keputusan: Permukaan sendi tempurung lutut didapati berbentuk bujur dengan nisbah lebar-tinggi bernilai 1.31. Purata ketebalan, kelebaran dan ketinggian tempurung lutut masing-masing adalah 20.7 mm, 40.7 mm dan 31.3 mm. Hanya 17.9% sepadan dengan saiz terkecil daripada ketiga-tiga pengeluar, sementara 57.6% tidak sepadan dengan semua implan. Implan bujur sesuai untuk 53.8% pesakit dan 46.2% pesakit sesuai dengan implan bulat berdasarkan nisbah lebar-tinggi mereka.

Kesimpulan: Pesakit wanita kami memiliki tempurung lutut yang lebih nipis dan kecil yang memerlukan implan yang lebih kecil berbanding dengan pesakit Barat. Oleh sebab itu, pengeluar implan ortopedik harus menimbang untuk memantapkan saiz implan dari segi ketebalan dan juga kelebaran.

Kata kunci; *Tempurung lutut, gantian sendi lutut, anatomi*.

ABSTRACT

Background: Patellofemoral joint is considered as a complex joint involving articulation between the patella and femoral trochlea. Loss of patella articular cartilage occurs in patellofemoral arthritis that may require patella arthroplasty in Total Knee Arthroplasty (TKA). Proper patella implant sizing is important to prevent implant failure. However implants used for TKA in Asian patients mostly produced based on anthropometry of the Western population. We conducted this study to define intra-operative anatomy of patella dimensions in our populations and compare it with current prosthetic systems.

Methods: This was a cross sectional study involving female patients who underwent Total Knee Arthroplasty in HUSM. Intra-operative anatomic measurements of 78 patellae with normal underlying bony structure were studied. Patella was measured using a surgical caliper which had sensitivity up to 0.5 mm. Patella dimensions that were measured including the patella height, width, thickness, medial and lateral articular facets width and thickness and patella circumference. Smallest implant size from 3 manufacturers were measured. Analysis using descriptive statistics was used to get the mean and median of anatomical patella dimensions, whereas Independent T test and One-Way ANOVA test were used to compare the female Malaysian patella dimensions with current prosthesis system sizing.

Results: The articular surface of the patella was found to have an oval shape with a width-height ratio of 1.31. The mean patella thickness, width and height were 20.7 mm, 40.7 mm and 31.3 mm respectively. Only 17.9% fit for smallest implant size from all 3 companies while 57.6% did not fit for all implants. Oval-shape implant was suitable in 53.8% patients while another 46.2% were suitable for round-shape implant based on their width-height ratio.

Conclusions: Our female patients have thinner and smaller patella which accommodate smaller patellar components than the Westerners. Therefore, the orthopaedic implant manufacturers have to consider optimizing the thicknesses as well as widths of their patellar prostheses.

Keywords: *Patella, total knee arthroplasty, anatomy.*

Chapter 1

INTRODUCTION

1.1 INTRODUCTION

The knee joint consists of two articulations which are tibio-femoral and patello-femoral articulations. The patello-femoral joints is considered as one of the most complex joints in the human body from the biomechanical aspect pertaining to its particular bone anatomy and the numerous capsuloligamentous structures as well as muscles that act dynamically on the patella (Zaffagnini *et al.*, 2013).

Patella is the largest sesamoid bone in the human body. This flat bone is curved proximally and tapered distally with some variation. As it poised like a shield over the anterior surface of the femoral condyles, this sesamoid bone lies deep to the fascia lata and the rectus femoris tendinous fibers while they course distally to the tibial tubercle (Bruce Reider, 1981). The posterior surface of the patella can be divided into superior articulating surface and inferior non-articulating surface. A vertical ridge further subdivides the superior part into medial and lateral facets. Patella can be categorised into 3 types, based on width dimensions of the medial (MAF) and lateral articular facets (LAF) (Wiberg, 1941). According to Wiberg's classification (Figure 1), a Type I patella is defined as MAF and LAF widths are concave and equal. A Type II patella is which the width of MAF is flat or slightly convex and smaller than the width of LAF. In Type III patella, the width of MAF is convex and considerably smaller than the width of LAF. Type II patella were the most prevalent as reported by Wiberg.

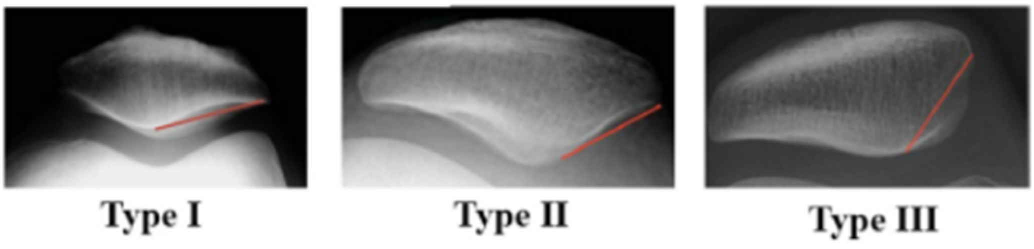

Figure 1 : Wiberg Classification for shape of patella.

The patellofemoral joint is an articulation between the patella and femoral trochlea. It is essential to knee stability mainly through its role in the extensor mechanism. The patella improves mechanical property of the extensor muscles by transmitting the extensor force across the knee at a greater distance from the center of rotation. The amplification of moment arm reduces the force required for the quadriceps to extend the knee by 15% to 30% (Goldblatt and Richmond, 2003).

Patellofemoral arthritis is a result of articular cartilage loss of the patella and the trochlear groove, where the chondral wear is most prominent in the lateral patellar facet. This points out that the lateral patellar facet receives higher load than the central or medial aspect of the patella (Kim and Joo, 2012). Clinically it presents with anterior knee pain either at rest or activities such as kneeling, squatting, climbings stairs and getting up from a chair.

Total knee arthroplasty (TKA) is indicated in symptomatic knee osteoarthritis and those who has failed non-operative treatments. One of its components is patella replacement.

A comprehensive knowledge of the anatomy of the patella is an essential prerequisite to understand the pathological changes that affect it. Patella thickness is a challenging concern during patellar resurfacing for TKA, in which a thin patella can lower patellofemoral contact force as well as poses the possible risk of stress fracture and anteroposterior instability (Kim *et al.*, 2009).

Anthropometric measurements of the patella and patella ligament are critical in the diagnoses and surgical corrections of knee-related injuries or disorders(Yoo *et al.*, 2007). A success in the functionality of knee arthroplasty is highly dependent on appropriate size and thickness of the chosen patella implant, whereas consequence of disproportional implant of the patellofemoral joint would be an ineffective lever support, limitation of motion, excessive wear and instability of the patella as well as associated knee pain(Iranpour *et al.*, 2008).

Poor design characteristics of the implants and technical errors were related to early patellar failures in tricompartmental TKA (Baldwin and House, 2005). During early years, the surgeon had bounded choice of implant due to limited number of sizes available for total knee prostheses. Over the years, advances and evolutions of the design and kinematics in TKA had led to better sizing options to more closely duplicate patient anatomy. Correct implant sizing can help to reduce complication rate and get the best outcome (Hitt *et al.*, 2003).

Currently, the surgeons must depend on the prostheses manufacturers to provide properly sized implants. After patella is resurfaced in TKA, various patella components are provided by manufacturers which allow the prostheses to be onset or inset using symmetrical or asymmetrical domes and anatomic design features (Schmalzried, 2002). Some systems concurrently highlight on replacing only the articular surface, maximizing the anatomic bony coverage, correct positioning of the dome, and restore the thickness of the dome as well as the medial and lateral facets (Baldwin and House, 2005).

Implants that being used for TKA in Asian patients mostly have been produced based on anthropometry of the Western population. There would be differences in terms of conformity of implants to the patient's anatomy and clinical results after TKA due to anatomic features and life styles dissimilarities between Western and Asian populations. For that reason, Asian surgeons are particularly concerned in related surgical techniques and implant designs that being used in TKA for better-quality clinical results as well as patient satisfaction (Kim *et al.*, 2015).

We conducted this study to define intra-operative anatomy of patella with normal underlying bony architecture from a group of patients undergoing TKA in Hospital USM and compare the measurements with the dimensions of current prosthetic systems. The goal is to get practical anatomic patella information in our population, to help in the development and improvement of patella component design and implantation in TKA among our population.

Chapter 2

OBJECTIVES OF THE STUDY

2.1. GENERAL OBJECTIVES

1. To study the anatomical data of patella dimensions collected from female patients undergoing total knee arthroplasty in Hospital USM.

2.2. SPECIFIC OBJECTIVES

1. To measure the intra-operative anatomy of patella dimensions in terms of patella height, width, width-height ratio and thickness.
2. To compare patella dimensions data collected in HUSM with the available current implants size in Hospital USM
   - The available implants are from 3 manufacturers : manufacturers A, B and C.
3. To determine whether oval or round patellar prosthesis is more suitable in patella arthroplasty relative to patella anatomy.

Chapter 3

MANUSCRIPT

TITLE: ANTHROPOMETRIC INTRAOPERATIVE MEASUREMENT OF THE PATELLA DIMENSIONS IN TOTAL KNEE ARTHROPLASTY OF FEMALE PATIENTS

Author: Dr. Nur Syahida Mohd Termizi

Department of Orthopaedics,

School of Medical Sciences, Universiti Sains Malaysia,

16150 Kota Bharu, Kelantan

Corresponding Author:

Dr Shaifuzain Ab Rahman

Department of Orthopaedics, School of Medical Sciences, Universiti Sains Malaysia,

Kota Bharu, 16150 Kota Bharu, Kelantan, MALAYSIA

Email: shaifu69@yahoo.com; Tel: +609-7676389; Fax: +609-7653370

Disclosure of funding:

None of the authors receive any financial support for this study

ABSTRACT

Background: Patellofemoral joint is considered as a complex joint involving articulation between patella and femoral trochlea. Loss of patella articular cartilage occurs in patellofemoral arthritis that may require patella arthroplasty in TKA. Proper patella implant sizing is important to prevent implant failure. However implants used for TKA in Asian patients mostly produced based on anthropometry of the Western population. We conducted this study to define intra-operative anatomy of patella dimensions in our female populations and compare it with current prosthetic systems.

Methods: This is a cross sectional study involving female patients who underwent total knee arthroplasty in HUSM. Intra-operative anatomic measurements of 78 patellae with normal underlying bony structure were studied. Patella was measured using a surgical caliper which had sensitivity up to 0.5 mm. Patella dimensions that were measured including the patella height, width, thickness, medial and lateral articular facets width and thickness and patella circumference. Smallest implant size from 3 manufacturers were measure. Analysis using descriptive statistics was used to get the mean and median of anatomical patella dimensions, whereas independent T test and One-Way ANOVA test were used to compare the female Malaysian patella dimensions with current prosthesis system sizing.

Results: The articular surface of the patella was found to have an oval shape with a width-height ratio of 1.31. The mean patella thickness, width and height were 20.7 mm, 40.7 mm and 31.3 mm respectively. Only 17.9% fit for smallest implant size from all 3 manufacturers while 57.6% did not fit for all implants. Oval-shape implant was suitable in 53.8% patients while another 46.2% were suitable for round-shape implant based on their width-height ratio.

Conclusion: Our female patients have thinner and smaller patella which accommodate smaller patellar components than the Westerners. Therefore, the orthopaedic implant manufacturers have to consider optimizing the thicknesses as well as widths of their patellar prostheses.

Keywords: *Patella, total knee arthroplasty, knee replacement arthroplasty, anatomy.*

INTRODUCTION

The patello-femoral joints is considered as one of the most complex joints in the human body from the biomechanical aspect pertaining to its particular bone anatomy and the numerous capsuloligamentous structures as well as muscles that act dynamically on the patella (Zaffagnini *et al.*, 2013).

Patella is the largest sesamoid bone, which shields over the anterior surface of femoral condyles and lies deep to fascia lata and the rectus femoris tendinous fibers while they course distally to the tibial tubercle (Bruce Reider, 1981). Its posterior surface can be divided into superior articulating surface and inferior non-articulating surface. A vertical ridge further subdivides the superior part into medial and lateral facets. Patella can be categorised into 3 types, based on width dimensions of the medial (MAF) and lateral articular facets (LAF) (Wiberg, 1941).

The patellofemoral joint is an articulation between the patella and femoral trochlea. It is essential to knee stability through its role in the extensor mechanism whereby patella improves mechanical property of extensor muscles via transmitting the extensor force across knee at a greater distance from center of rotation. The magnification of moment arm reduces quadriceps force to extend the knee by 15% to 30% (Goldblatt and Richmond, 2003).

Patellofemoral arthritis is a result of articular cartilage loss of the patella and the trochlear groove, where the chondral wear is most prominent in the lateral patellar facet. This points out that the lateral patellar facet receives higher load than the central or medial aspect of the patella (Kim and Joo, 2012). Clinically it presents with anterior knee pain either at rest or with activities such as kneeling, squatting, climbings stairs and getting up from a chair.

Total knee arthroplasty (TKA) is indicated in symptomatic knee osteoarthritis and those who has failed non-operative treatments with patella replacement being one of its components.

An ample knowledge of anatomy of the patella is essential to understand the pathological changes that affect it. (Kim *et al.*, 2009). Anthropometric measurements of the patella and patella ligament are critical in the diagnoses and surgical corrections of knee-related injuries (Yoo *et al.*, 2007). A success in functionality of knee arthroplasty highly depends on appropriate size and thickness of the chosen patella implant (Iranpour *et al.*, 2008).

Poor design characteristics of the implants and technical errors were related to early patellar failures in tricompartmental TKA (Baldwin and House, 2005). In early years, limited numbers of implant sizes were available for total knee prostheses. However, evolutions of the design and kinematics in TKA led to better sizing options to more closely duplicate patient's anatomy which help to reduce complication rate and to get the best outcome (Hitt *et al.*, 2003).

Currently, surgeons depend on the manufacturers to provide properly sized implants. Various patella components are available after resurfacing, which allow the prostheses to be onset or inset using symmetrical or asymmetrical domes and anatomic design features (Schmalzried, 2002). Some systems highlight on replacing only the articular surface, maximizing the anatomic bony coverage, correct positioning of the dome and bring back the thickness of the dome as well as the medial and lateral facets (Baldwin and House, 2005).

Implant components used for TKA in Asian patients mostly produced based on anthropometry of the Western population. There would be differences in terms of conformity of implants to the patient's anatomy and clinical results after TKA due to anatomic features and life styles dissimilarities between Western and Asian populations. For that reason, Asian surgeons are particularly concerned in related surgical techniques and implant designs that being used in TKA for better-quality clinical results as well as patient satisfaction (Kim *et al.*, 2015).

This study was conducted to define intra-operative anatomy of patella dimensions with fairly normal underlying bony architecture from a group of patients undergoing TKA in Hospital USM and compare it with the current prosthetic systems sizing. The goal is to get practical anatomic patella information in our population. It is also to help in the development and improvement of patella component design and implantation in TKA among our population.

METHODOLOGY

This was a cross-sectional study carried out at Hospital Universiti Sains Malaysia(HUSM) for a period of 12 months from July 2016 to July 2017. All female patients who underwent total knee arthroplasty (TKA) in HUSM during this period of study were selected to involve in this study. A total of 78 patients agreed to participate in the study. All of them successfully underwent TKA. Patients who had severe patella deformity from previous trauma, severe osteoarthritis of patellofemoral joint or congenital deformity that normal anatomy could not be determined were excluded from this study. The sample size was calculated using ‘Sample Size Formula to Estimate a Mean’.

Initial detailed and thorough explanation regarding the TKA procedure was done by Arthroplasty Surgeon during consultation at the Orthopaedic clinic. Verbal and written consents to participate in this study were obtained prior to operation.

During the operation, patient was placed in supine position. Intraoperative anatomic measurement of patella was done by 2 arthroplasty surgeons using a surgical caliper which had sensitivity up to 0.5 mm.

Patella dimensions that were measured include the patella height, which was from the edge of the superior articular surface to the margin of the inferior articular surface, the patella width, which was from the border of the medial articular surface to the border of lateral articular surface, and the patella thickness, which was the maximum thickness measured at the center of the dome using caliper (Baldwin and House, 2005). In addition, the widths of medial and lateral facets as well as their thickness were also measured. Finally, the circumference of the patella was traced using the cerclage wire. The estimated time taken for the measurement was about 5 minutes, which was added to the normal time taken for TKA procedure. All measurements were recorded in the data collection sheet (Study Proforma).

The operation for TKA in Hospital USM uses implants from 3 different manufacturers, depending on financial cost. Each company has various size of implant from small to large size. The smallest implant size for the patella from each company was measured.

Data was entered, cleaned and analyzed using the predictive analysis software IBM SPSS version 22 including descriptive statistics and independent T test. Confidence interval was set at 95% and a p value < 0.05 was considered statistically significant.

RESULTS

This study involved 78 female patients who underwent TKA**.** The patients were between 40 to 79 years old with mean age of 65.5 years old (SD 7.41). Out of 78 patients, 72 (92.3%) are Malays, 5 (6.4%) are Chinese and 1 patient (1.2%) is an Indian.

All measured patellae were able to be included in the study. The patella thickness range from 18 to 26 mm with mean 20.74 mm (1.85). Patella height range from 22 to 38 mm with mean 31.33 mm (2.81). Patella width range from 31 to 51 mm with mean 40.76 mm (3.79). MAF width range from 13 to 27 mm with mean 19.38 mm (2.70). LAF width range from 15 to 28 mm with mean 21.30 mm (2.27). MAF thickness range from 11 to 20 mm with mean 15.90 mm (2.24). LAF thickness range from 12 to 22 mm with mean 16.93 mm (2.16). Width-height ratio range from 0.97 to 1.68 with mean 1.31 (0.13). These results were summarized in Table 1.

Out of 78 patients, 41 (52.6%) were measured from right knees, while 37 (47.4%) were left knees. Based on Wiberg Classification (Wiberg, 1941), 47 (60.3%) patellae were Type I patella, 26 (33.3%) were Type II and 5 (6.4%) were Type III patella.

The mean patella dimensions including patella height, patella width, patella thickness, MAF width and LAF width between right side and left side was not statistically significant different with p-value more than 0.05 (Table 2). The mean patella thickness and patella width between Wiberg type was also not statistically different (p-value > 0.05) (Table 3).

Correlation between patella height, patella width, patella thickness, MAF width, LAF width, MAF thickness and LAF thickness were analysed using Pearson correlation. It showed perfect correlation between MAF width and LAF width with patella width. There were moderate to good correlation between patella width and patella thickness as well as between MAF thickness and patella thickness. However, there were little or no correlations between LAF and MAF width, MAF thickness and patella height, MAF thickness and LAF width, LAF width and LAF thickness as well as LAF and MAF thickness.

Based on measurement of patella dimensions, we proceeded with further analysis comparing patients' patella with implants size. Out of 78 patients, 33 patients were fit for smallest implant size from manufacturer A and C while only 14 patients were fit for smallest implant size from manufacturer B. In general, only 14 (17.9%) patients fit for smallest implant from all 3 manufacturers, 19 (24.3%) patients fit for smallest implant from 2 out of 3 manufacturers while another 45 (57.6%) patients did not fit for all implants. 42 patients (53.8%) were suitable for oval-shape implant while another 36 (46.2%) were suitable for round-shape implant, based on their width-height ratio.

The smallest diameter of implant by manufacturer A is 30 mm. The mean patella height between group of patients who fit the manufacturer A implant versus the non-fit group was statistically significant different with p-value < 0.001. The mean patella height in patients who fit the manufacturer A implant were higher compared to the mean patella height in the non-fit group by 4.18mm mean difference. The mean patella width between group of patients who fit the manufacturer A implant versus the non-fit group was statistically significant different with p-value < 0.002. The mean patella width in patients who fit the manufacturer A implant were larger compared to mean patella width in the non-fit group by 2.68mm mean difference (Table 4).

The smallest diameter of implant by manufacturer B is 32 mm. The mean patella height between group of patients who fit the manufacturer B implant versus the non-fit group was statistically significant different (p-value <0.001). The mean patella height in patients who fit the manufacturer B implant were higher compared to the mean patella height in the non-fit group by 4.99mm mean difference. The mean patella width between group of patients who fit the manufacturer B implant versus the non-fit group was statistically significant different (p-value $=0.002$). The mean patella width in patients who fit the manufacturer B implant were larger compared to mean patella width in the non-fit group by 3.43mm mean difference (Table 4).

The smallest diameter of implant by manufacturer C is 30 mm. The mean patella height between group of patients who fit the manufacturer C implant versus the non-fit group was statistically significant different (p-value <0.001). The mean patella height in patients who fit the manufacturer C implant were higher compared to the mean patella height in the non-fit group by 3.86mm mean difference. The mean patella width between group of patients who fit the manufacturer C implant versus the non-fit group was statistically significant different (p-value < 0.001). The mean patella width in patients who fit the manufacturer C implant were larger compared to mean patella width in the non-fit group by 2.37mm mean difference (Table 4).

The mean width-height ratio between group of patients suitable for oval-shape implant and round-shape implant was statistically significant different with p-value less than 0.001. The mean width-height ratio of patients suitable for oval-shape implant were bigger compared to mean width-height ratio of patients suitable for round-shape implant, but with only 0.20 mean difference between this two groups. The mean patella height between group of patients suitable for oval-shape implant and round-shape implant was statistically significant different (p-value <0.001). The mean patella height of patients suitable for round-shape implant were higher compared to mean patella height of patients suitable for oval-shape implant with 2.50 mean difference between this two groups (Table 5).

DISCUSSION

Anthropometric measurements of the patella and patella ligament are critical in the diagnoses and surgical corrections of knee-related injuries (Yoo *et al.*, 2007). A success in functionality of knee arthroplasty is highly depends on appropriate size and thickness of the chosen patella implant (Iranpour *et al.*, 2008). Poor design characteristics of the implants and technical errors were related to early patellar failures in tricompartmental TKA (Baldwin and House, 2005). In this study, we aimed to document the anthropometric measurement of patella dimensions among our female patients receiving TKA and compare it with the available current patella implants size.

We only included female patients in this study as majority of our patients who underwent TKA were females. In general, female is expected to have smaller patella dimensions, thus it is appropriate to compare only our female population with the smallest available patella component. However, it would have been interesting to see if the result is significantly different when compared to male patella dimensions.

In the present study, the mean patella thickness, patella width and patella height were 20.7 mm, 40.7 mm and 31.3 mm respectively. In an American study (Baldwin and House, 2005), the mean patella thickness was 21.8 mm, mean patella width was 42.7 mm and mean patella height was 35.0 mm in their female samples. Another African study (Olateju *et al.*, 2013) showed mean patella thickness, patella width and patella height were 22.8 mm, 42.7 mm and 41.0 mm respectively among their female samples. These studies showed that our populations have thinner and smaller patellae than the Westerners.

A thick patella can displace the patellar tendon further from the tibio-femoral contact point, but the moment arm is only sensitive to patellar thickness at flexion angles less than 35°due to low force being transmitted from the quadriceps tendon to the patellar tendon at high flexion angles, even when the patella is thick (Yamaguchi and Zajac, 1989). Hence, inappropriate sizing of patella implant may have probability of influencing risk of implant failure among our populations which have thinner patellae as compared to Westerners.

Hsu (Hsu *et al.*, 1996) concluded that it is necessary to restore the original patellar thickness after resurfacing to prevent decrease range of motion of the knee, patellar subluxation as well as stress fractures. Reuben (Reuben *et al.*, 1991) suggested a minimum of 15-mm residual bony patellar thickness to minimize the incidence of patellar stress fractures. However, recent study by Koh (Koh *et al.*, 2002) claimed that having a residual bony patellar thickness of less than 12 mm did not lead to an inferior clinical outcome and did not increased complication rate in patients undergoing TKA. Therefore, preservation of a minimum of 12 mm of bony thickness is agreed by majority arthroplasty surgeon (Koh *et al*., 2002).

A study by Bengs (Bengs and Scott, 2006) suggested that, in the typical knee undergoing TKA, intraoperative flexion and patellar tracking may not be particularly sensitive to composite patellar thickness and they continue to recommend bone stock maintenance and restoration of native patellar thickness when resurfacing the patella.

In our study, Type I patellae which are those MAF and LAF widths are concave and equal, were the most prevalent with 60.3% of the patients as compared to 33.3% Type II patellae. This is different from the study by Wiberg in 1941 that reported Type II patellae based on Wiberg's classification were the most prevalent, supported by another study by Fucentese (Fucentese *et al.*, 2006).

In patellofemoral arthritis, the chondral wear is most prominent in the lateral patellar facet which points out that the lateral patellar facet receives higher load than the central or medial aspect of the patella (Kim and Joo, 2012). In view of majority of our patients had equal patella MAF and LAF widths with higher load on lateral facet, the risk of developing patellofemoral arthritis might be higher. Another supportive evidence that the highest compressive load found primarily beneath the lateral facet are related to the higher subchondral bone densities found in the proximal part of the lateral facet (Eckstein *et al.*, 1992) as it has been described that patellar trabecular bone architecture is a non-homogenous stacking up of sheets resulting from improved remodelling process (Townsend *et al.*, 1976).

Our results also showed perfect correlation between MAF width and LAF width with patella width. There were moderate to good correlation between patella width and patella thickness as well as between MAF thickness and patella thickness. Observation of good correlation between patella width and thickness is in agreement with the results of Iranpour (Iranpour *et al.*, 2008) and Olateju (Olateju *et al.*, 2013). Patella width has been proposed to be a dependable factor for predicting the normal size of patella thickness, which helps the surgeons to decide on the thickness of the patella prosthesis during TKA (Iranpour *et al.*, 2008).

Our findings showed that 33 patients (42.3%) fit the smallest patella implant provided by 3 manufacturers which justify why majority of surgeons in Asia do not replace patella. Our findings was also in accordance with an American study (Clarke and Spangehl, 2014) that showed about one third of female patients have native patellae that measure about 17 to 21 mm thick and is big enough to accommodate a patella implant that is between about 26 and 33 mm in diameter without overhang. In order to avoid over resection of remaining bone stock and at the same time restore the original patella thickness, they suggested prostheses in the diameter range of about 26 to 33mm need to be available in thicknesses of approximately 5 to 7 mm. Unfortunately, it is apparent that most manufacturers do not offer components that are optimized to the dimensions of the native female patella (Clarke and Spangehl, 2014).

Other authors have reported that the patella articular surface is oval with the width being larger than the height (Bruce Reider, 1981) (Baldwin and House, 2005). The ratio of width to height in this series was 1.31, similar to findings by Aglietti (Aglietti *et al.*, 1975) which was also 1.31and ratio of 1.34 by Reider (Bruce Reider, 1981). The point that the mean articular surface of patella is 25% wider than its height could be a significant consideration in patella prosthesis design. An American study by Baldwin (Baldwin and House, 2005) showed that there is potential to improve maximum patellar coverage by 9.1% if the surgeon uses an oval patella implant, with 11.5% improvement of coverage in men and 7.7% in women, which will reduce load transfer through the implant.

Strength of Study

The previous studies have chosen different measuring techniques, including measurements taken in cadaveric study and the use of radiographs in an attempt to get the patella dimensions. The good point of radiographic study is the availability of large sample size as compared to intraoperative measurements. However, there is limitation in accuracy of the measurements due to magnification in radiograph as well as thickness of the patella cartilage that cannot be measured on radiograph. Whereas for cadaveric study, limited number of cadavers is the negative point.

Limitations

Still, there were several limitations present in this study. First, regarding the number of patients involved in this study. We require a larger sample size with multicenter involvement to get better results. Second, a surgical caliper was used to measure the patella dimensions. Even though caliper measurements are commonly used in anthropometric studies, a question raised regarding accuracy of smooth caliper measurements (Rauh *et al.*, 2002). Lastly, the knees that were measured had advanced osteoarthritis requiring TKA. Although we minimized bias by excluding severely deformed patella from previous trauma or severe osteoarthritis or congenital that normal anatomy could not be determined, it is rational to assume that all patellae were diseased to some extent. Hence, patella dimensions as well as positions of median ridge may be different from those of non-disease patellae. Still, we believe that this study offers valuable information required for TKA where pathologic anthropometric information is needed.

CONCLUSION

As a conclusion, based on the results obtained from this study, the implant manufacturers will have to consider ideal size of patella component for Asian patients especially female. This is to provide optimum patella resurfacing technique in a tricompartmental TKA.

TABLES AND FIGURES

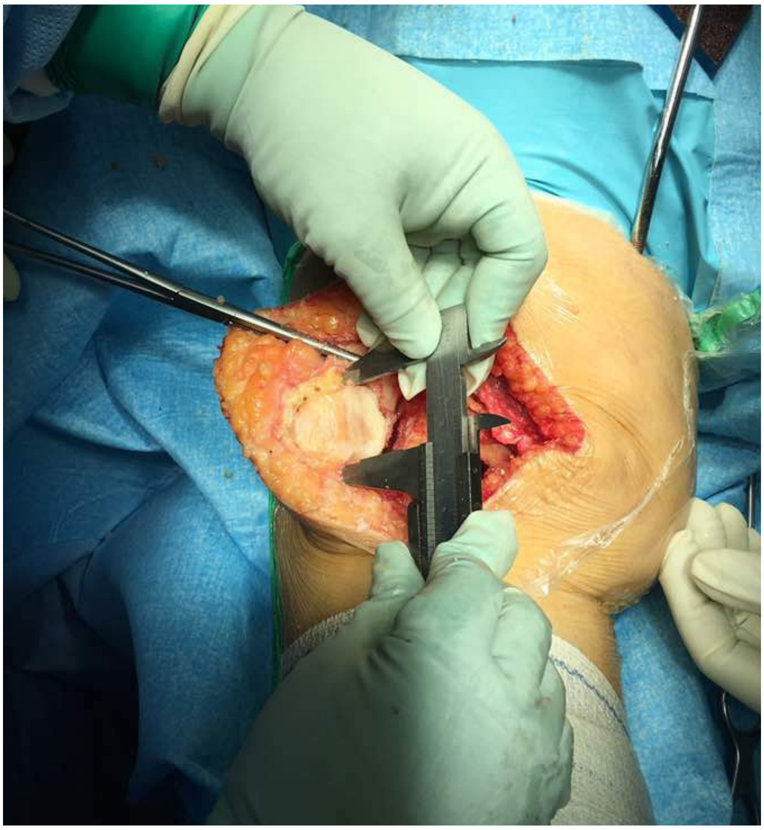

Figure 1 : Measurement of patella dimensions using caliper.

Figure 2 : Circumference patella measurement using circlage wire.

Table 1 : Descriptive analysis for this study.

Variables	Mean (SD)
Age	65.50 (7.41)
Patella Thickness	20.74 (1.85)
Patella Height	31.33 (2.81)
Patella Width	40.76 (3.79)
MAF Width	19.38 (2.70)
LAF Width	21.30 (2.27)
MAF Thickness	15.90 (2.24)
LAF Thickness	16.93 (2.16)
Width-height Ratio	1.31 (0.13)

Table 2 : Patella dimensions between right and left side by Independent T Test (n=78).

Variable (mm)	Right side, Mean(SD)	Left side, Mean(SD)	Mean difference (95% CI)	t statistics (df)	p value
Patella height	31.41(2.88)	31.24(2.77)	0.17 (-1.11, 1.45)	0.27 (76)	0.790
Patella width	40.67(3.62)	40.85(4.02)	-0.18(-1.90,1.54)	-0.21(76)	0.835
Patella thickness	20.82(2.06)	20.65(1.61)	0.17(-0.67,1.01)	0.40(76)	0.691
MF width	19.22(2.66)	19.55(2.77)	-0.33(-1.56,0.89)	-0.54(76)	0.588
LF width	21.30(2.35)	21.30(2.20)	0.01(-1.02,1.04)	0.02(76)	0.988

Table 3 : Patella thickness and width compared with Wiberg Type using One-Way ANOVA test (n=78).

Variable (mm)	**Wiberg Type 1, Mean(SD)**	**Wiberg Type 2, Mean(SD)**	**Wiberg Type 3, Mean(SD)**	**F-statistics (df)**	**p value**
Patella thickness	20.71(1.67)	20.81(2.29)	20.60(1.14)	0.04 (77)	0.965
Patella width	41.03(3.81)	40.02(3.85)	42.00(3.32)	0.88 (77)	0.418

Table 4 : Comparison of patella height and patella width between group of patients who were fit and not fit with implant from manufacturer A, B and C by Independent T Test (n=78).

Manufacturer	**Variable (mm)**	**Fit, Mean (SD)**	**Not Fit, Mean (SD)**	**Mean diff. (95% CI)**	**t statistics (df)**	**p value**
A	Patella height	33.74(1.84)	29.57(1.96)	4.18 (3.30, 5.05)	9.55 (76)	<0.001
	Width	42.30(4.09)	39.62(3.14)	2.68(1.05, 4.31)	3.27 (76)	0.002
B	Patella height	35.43(1.60)	30.44(2.14)	4.99(3.78, 6.20)	8.21 (76)	<0.001
	Width	43.57(2.96)	40.14(3.69)	3.43(1.33, 5.53)	3.25 (76)	0.002
C	Patella height	33.61(1.70)	29.75(2.30)	3.86(2.91, 4.81)	8.07 (76)	<0.001
	Width	42.16(4.07)	39.78(3.29)	2.37(0.71, 4.04)	2.84 (76)	0.006

Table 5 : Comparison of width-height ratio and patella height between group of patients suitable for oval-shape implant and round-shape implant by Independent T Test (n=78).

Variable (mm)	**Oval, Mean(SD)**	**Round, Mean(SD)**	**Mean difference (95% CI)**	**t statistics (df)**	**p value**
Width-height ratio	1.40(0.09)	1.20(0.06)	0.20 (0.16, 0.23)	11.18 (76)	<0.001
Patella height	30.18(2.51)	32.68(2.56)	-2.50(-3.64,-1.36)	-4.35(76)	<0.001