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Total knee arthroplasty : the Asian perspective on patient outcome, implants and complications

Budhiparama, N.C.

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Total knee arthroplasty

The Asian perspective on patient outcome,
implants and complications



Nicolaas C. Budhiparama

Total knee arthroplasty

The Asian perspective on patient outcome, implants and complications

Nicolaas Cyrillus Budhiparama, Jr.

PhD thesis, Leiden University Medical Center, Leiden, Netherlands

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The Asian perspective on patient outcome, implants and complications

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Promotor

Prof. dr. R.G.H.H. Nelissen

Prof. dr. S. Parratte

Institute for Locomotion, Aix-Marseille University
& International Knee & Joint Center, Abu Dhabi

Promotiecommissie

Prof. dr. J.A.N. Verhaar

Prof. dr. T.P.M. Vliet Vlieland

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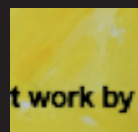
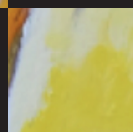
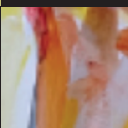
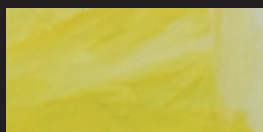
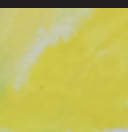
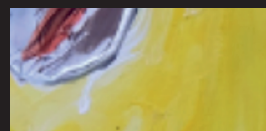
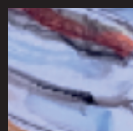
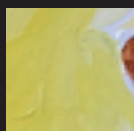
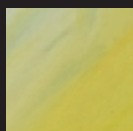
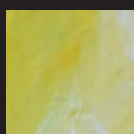
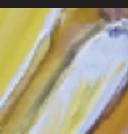
Ngelmu pari tansaya isi tansaya
tumungkul. Seperti ilmu padi, kian
berisi kian merunduk.

(Javanese / Indonesian Proverb)

Meaning: The higher your education, the humbler you
should be.

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Chapter

1

General Introduction

Total knee arthroplasty (TKA) is considered to be the treatment of choice for end-stage knee osteoarthritis¹⁻³ with patient satisfaction ranging from 75% to 89%.³⁻⁷ Many factors contribute to the outcome of TKA, which are disease associated such as preoperative severity of osteoarthritis. Secondly, surgical associated factors, such as the implant, surgical technique and complications will have an impact on outcome of TKA in patients. Finally, patient associated like patient's functionality (both preoperative and postoperative) and expectations on outcome.

As for the most commonly treated disease with a TKA, osteoarthritis (OA), it is the most common form of arthritis and the most prevalent chronic joint disease. It is a multifactorial, inflammatory and degenerative joint disorder, characterized by degeneration of articular cartilage, intra-articular inflammation with synovitis, and changes in the peri-articular and subchondral bone. It has a complex pathogenesis due to the combination of genetic, metabolic and local factors. Nowadays, OA pathogenesis has shifted from a classical concept due to age factors, into a multifactorial disease.⁸⁻¹¹ The prevalence of osteoarthritis is influenced by various factors such as age, sex, race, lifestyle, obesity, occupation, and genetics. The population of Indonesia is projected to increase to 268 million population in 2020. During a regional survey in Indonesia on a small patient cohort who had musculoskeletal pain, 36% of those patients had osteoarthritis, gout, or spine problems.¹² National data on the incidence and prevalence of knee osteoarthritis in Indonesia are not available yet. According to the WHO, the worldwide prevalence of knee osteoarthritis is 10% in men and 18% in women older than 60 years.

Cytokines play an important role in the expression of osteoarthritis. For that matter secretion of tumor necrosis factor alpha (TNF- α) and interleukin-1 β (IL-1 β), the active form of IL-1 during inflammation, are increased in the OA-affected cartilage and synovial cells.⁵ Current concepts define OA as a genetic disease, which is influenced by environmental factors. For that matter, 65% of radiographic OA of the knee can be associated with multiple gene interactions.^{8,13} Genes implicated in OA include gene codes for vitamin D and its receptor (VDR), iodothyronine-deiodinase enzyme type 2 (DIO2), type II collagen (Col2A), insulin-like growth factor 1 (IGF-1), transforming growth factor β (TGF- β), estrogen receptor α (ER α), and others genetic still in research with GWAS (genome-wide association studies). However, since environmental factors have a huge impact on OA development, research into single-nucleotide polymorphisms (SNPs) became the focus area for pharmacological agents. Therefore, OA treatment should be holistic and should be addressed in a step-care strategy, starting with conservative treatment using both non-pharmacological (exercise, diets, etc.)^{14,15} as well as pharmacological interventions. As a last resort TKA can be used as a treatment for end-stage knee OA.¹⁶

Since OA patients usually present with complaints of pain limiting daily living activities, treatment is focussed on reducing pain. Therefore, the first choices of medication are Acetaminophen, NSAIDs, and COX-2 inhibitors.^{17,18} Other drugs, such as glucosamine

sulfate and chondroitin sulfate claim to have effects on pain and joint space narrowing, but placebo-controlled randomized studies show no effects.^{19,20} Steroid injection is used to treat local active joint inflammation but showed no functional improvement either.²¹ Newer pharmacological OA treatments focus on decreasing the progression of OA. Oral Doxycycline, Strontium ranelate, Cathepsin K inhibitors, Calcitonin, anti-enzyme drugs like estrogen, PTH and its analogues Bone morphogenetic proteins (BMPs), Sprifermin are still being studied. Moreover, anti-inflammatory agents against IL-1, IL-6, and TNF- α have not shown a significant effect in OA treatment yet.^{22,23}

Surgical associated factors for outcome in total knee arthroplasty

Surgical treatments considered for late knee OA, include osteotomy around the knee, joint distraction procedure, unicondylar knee replacement, and total knee arthroplasty (TKA).²⁴

In Indonesia there is an expected increase in TKA surgery due to several factors:

1. increased aging population, the current mean life expectancy is 69 years²⁵
2. since 2016, the National health care insurance coverage includes TKA procedures
3. increased education and training of orthopaedic surgeons in knee arthroplasty through Indonesian Hip & Knee Society fellowships from 2 fellows per year to 60 fellows per year.

Many factors contribute to the outcome of TKA such as preoperative severity of OA and knee deformity as well as implant related factors such as optimal fit of the implant and surgical correction of the deformity. Several surgical techniques and types of implants are designed to improve patient satisfaction and functionality. A wide range of different surgical techniques are available to achieve an optimal result for TKA. Optimal implant positioning is claimed to be achieved by computer-assisted navigation and patient-specific instrumentation (PSI), recently accelerometer-based navigation has been added to improve TKA positioning.^{26–29}

Implant survival (end-point revision) can be influenced by implant design.^{30–32} Knee implant fit to the patient's knee anatomy is associated implant longevity.³³ Interestingly, overhang or under-hang of knee components do not command poorer patient-reported outcome.^{33–35}

Patient associated factors are based on the patient's ability to cope with preoperative knee complaints, postoperative pain perception and the interaction with the orthopaedic surgeon. Thus, a complex entity, which will be different in different social cultural contexts. Patient satisfaction is a very important tool for measuring the success of TKA, whether the procedure has attained the goals of TKA in relieving pain and restoring function. The success of a technical operation in surgeons' perspective may not be the same as their patients. For that matter, a successful surgery by the surgeon's standard might be considered a failure in the patients' perspective.³⁶ Patient satisfaction is associated with

preoperative patient's expectation, functional outcome, mental health and to a lesser extent co-morbidity. The most important factor attributed to a patient's satisfaction is the patient's expectation and mental health while the most significant predictor for dissatisfaction is a pain, pessimism, treatment credibility, and treatment expectancy.³⁷⁻⁴² Therefore, the focus areas of research in the last decade puts more emphasis on the patient-reported outcome (PRO) and how to mediate it, next to the physician and gait analysis outcome measures.⁴³ Traditionally, TKA success is evaluated by the failure of the implant, indicated inversely as the survival of the implant³⁶, postoperative complications, morbidity, and mortality.⁴⁴ Those criteria are considered objective from the surgeon's point of view.⁴⁵ The modern approach to outcome measures has shifted towards more subjective criteria, which are based on the patient's perception, his or her quality of life improvements as a result of the TKA.⁴⁴ Patients' opinions on treatment outcome are of paramount importance when evaluating the success of TKA procedures.^{38,40,41,46} The International Consortium for Health Outcomes Measurement (ICHOM) Working Group has already published a consensus report defining an international standard set of outcome measures for patients with hip or knee osteoarthritis that can be used widely for monitoring, comparing, and improving healthcare on outcomes that matter most to patients. In assessing outcome measurements, ICHOM included a standard set that consist of patient-reported health status, surgical outcomes, and disease progression. Several authors^{38,39,41,47} studied the predictive factors of outcome in TKA and showed that the preoperative functional score, radiological measurement of OA grades as well as femorotibial joint angles were associated with the postoperative functional score.^{38,39,41,47} Another study by Matsuda et al showed that the surgical intervention itself, such as avoiding varus alignment and achieving a better Range of Motion (ROM), increases patient satisfaction and thus meets preoperative patients' expectations.⁴⁸ Patient's dissatisfaction is usually related to residual pain, less functional outcome or unfulfilled patient's pre-operative expectation.^{49,50} Ultimately, the latter is the most important factor determining a good result of TKA.^{37,39,40,51} The most important factor contributing to patient dissatisfaction is post-operative residual pain, which in the majority is related with the anterior part of the knee (anterior knee pain -AKP). The incidence of AKP is 20%^{31,50} and its origin is multifactorial although it seems to be located at the patellofemoral joint in 40 – 58%. Knowledge of the anatomy of the patella, biomechanics of the patellofemoral joint, and implant design are very important to reduce AKP.⁵² Controversies regarding patellar resurfacing are still unresolved^{53,54}, the decision depends on the surgeon's discretion, influenced by both medical and non-medical reasons.⁵⁵ Regarding the anatomy of the patella, pre-operative patella baja has a higher post-operative patellar fracture compared with patella alta in TKA with the resurfaced patella.⁵⁶ It is caused by an intimate interaction of functional (muscle imbalance, dynamic valgus) and me-

chanical factors (incorrect component placement, aseptic loosening) as well as patients expectations regarding outcome.⁷

Several patient-associated factors described above, such as preoperative knee complaints and postoperative pain perception, have some fundamental discrepancies between different social cultural background. Asians are found to squat and kneel more frequently than the Western populations.⁵⁷ As a lower-to-middle income country, Indonesians have an inferior socioeconomic background that could influence the patient's preoperative status, which in turn determine their subjective satisfaction after TKA.⁵⁸

In addition, one of the patient-associated factors that could influence the outcome of TKA is racial discrepancies on knee anthropometric. Asians are known to have smaller knee compared to Caucasian. Since most TKA systems were based on North American and European anatomy, implant fit could be a major problem for Asians. It is essential to evaluate the difference of implant fit in Asian compared to Caucasian, to encourage the need of new TKA system based on Asian knee anthropometric. These anatomic differences may influence the alignment goal and intraoperative bone cut. In the end, the adjustment of component placement also depends on the knee anthropometric. Although knee anthropometric might not directly associated with functional outcome, but component incompatibility or implant-bone unfit associated with it. Besides anthropometric, socioeconomic-cultural also contribute to, not only functional outcome but also patient's expectation and perception. In addition, racial differences could harbor discrepancy over postoperative complication, especially in VTE. Different approach might be needed in VTE prevention for Asian patients.

Aims of this thesis

This thesis aims to address some of the aforementioned aspects associated with the outcome of total knee arthroplasty in Asian patients. These factors can be distinguished into patient associated factors (i.e. anthropometry, comorbidity, patient-perceived outcome) and surgical technique associated factors. Finally, the thesis also reviewed one of the devastating complications of TKA, that is, venous thromboembolism.

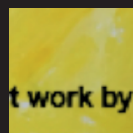
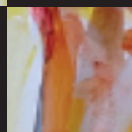
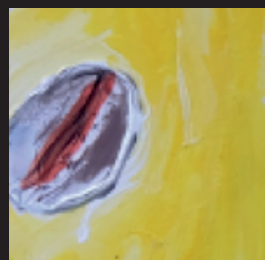
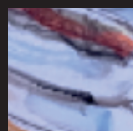
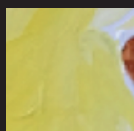
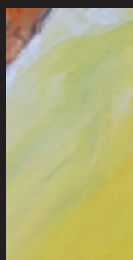
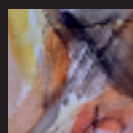
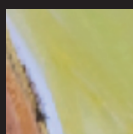
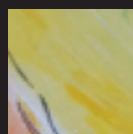
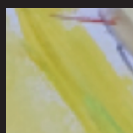
1. Patient factors
 - Anthropometric difference between knees of Indonesian Asians and Dutch Caucasians and the fit of nine different knee implant systems (**Chapter 2**)
 - Patient perception of the outcome between Indonesians and North Americans (**Chapter 3**)
2. Surgical factors
 - Effect of circumferential cauterization in unresurfaced patella in TKA (**Chapter 4**)
 - The usefulness of accelerometer-based navigation in TKA (**Chapter 5**)
3. Consideration on postoperative thromboembolic prophylaxis
 - Review of VTE prophylaxis in hip and knee arthroplasty (**Chapter 6**)

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Chapter 2

Mismatch between nine knee implant systems and Indonesian and Dutch anthropometric knee measurements: a cross-cultural phenomenon

Budhiparama N.C.
Lumban-Gaol I.
Ifra N.N.
De Groot P.C.J.
Utomo D.N.
Nelissen R.G.

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ABSTRACT

Purpose. The aim of this study was to evaluate the anthropometric differences between knees of Indonesian Asians and Dutch Caucasians and the fit of nine different knee implant systems.

Methods. A total of 268 anteroposterior (AP) and lateral knee preoperative radiographs of 134 consecutive patients scheduled for total knee arthroplasty at two different centers in Jakarta and Leiden were included. Both patient groups were matched for age and sex and included 67 Asians and 67 Caucasians. We assessed the radiographic difference between Asian and Caucasian anthropometric data. The dimensions of the nine knee implant designs (Vanguard, Genesis II, Persona Standard, Persona Narrow, GK Sphere, Gemini, Attune Standard, Attune Narrow, and Sigma PFC) were compared with the patients' anthropometric (distal femur and proximal tibia) measurements.

Results. The Dutch Caucasian patients had larger mediolateral (ML) and AP femoral and tibial dimensions than the Indonesian Asians. The aspect ratios of the distal femur and tibia were larger in the Asians. The AP and ML dimensions were mismatched between the tibial components of the nine knee systems and Asian anthropometric data. Both groups had larger ML distal femoral dimensions than the knee systems.

Conclusion. Knee dimensions significantly differed between and within the patient groups. Both groups had knee phenotypes beyond the size ranges of the nine knee systems. Increasing the range of the tibial and femoral components for the AP dimensions will increase the percentage of optimal fit for both Asian and Caucasian patients.

INTRODUCTION

An increase in the demand for total knee arthroplasty (TKA) is expected worldwide, especially in Asia, within the next 10 years.^{19,23} Data from national registries with 100% coverage and 99% completeness, such as those of the Netherlands, show an average increase of 20% during the last 5 years.⁹ Although these valid data are available for most Scandinavian countries, the England and Wales, Australia, New Zealand, and the Netherlands, the increase in the number of TKA cases in other populations is only an estimate or even unknown. More important is the outcome of these TKA procedures, not only for patients but also for determining the economic burden to society. The outcome of TKA is determined by patients' expectations and surgical aspects related to knee prosthesis position with respect to the anatomy of the patients.^{5,38,40} In line with this, patient expectations and the surgical aspects of implant positioning and functional knee phenotypes¹⁴ are intricately linked. Adequate coverage of the resected bony surfaces by the artificial knee design is important to minimize progressive implant migration, which ultimately causes implant loosening.^{15,25,28,31,37,38} Aside from the lower likelihood of implant loosening due to less than optimal implant positioning, a good component fit to the patient's knee also leads to fewer complaints.^{11,17,25,40} Anthropometric measurements vary between patients' joints; however, only a few TKA system designs that optimally fit the patients' knees are available. Most knee implants are based on North American and European patients. Although these continents have varied ethnic populations, the implant designs are mainly based on the average male Caucasian knee.²⁰ An increasing demand for TKA in Asia is to be expected. Whether the currently available total knee designs optimally fit Asian patients remains to be elucidated. In a study of approximately 1000 Asian, Caucasian, and African American subjects, Mahfouz et al. showed significant differences in the dimensions of the knee anatomy not only between sexes but also among the three ethnicities.²⁴ These anatomical size differences among ethnicities have also been substantiated in a systematic review by Kim et al.²⁰

The present study aimed to compare anthropometric knee measurements of Indonesian Asian and Dutch Caucasian patients scheduled for TKA with the dimensions of nine commonly used total knee systems. We hypothesized that owing to knee anthropometry differences between Asians and Caucasians, different TKA systems are needed. To our knowledge, this is the first study that compared the Asian and Caucasian populations with respect to the optimal fit of nine currently used TKA systems.

MATERIALS AND METHODS

A consecutive retrospective study was performed in 100 consecutive Asian patients scheduled for unilateral TKA in Jakarta, Indonesia. The inclusion criteria were knee osteoarthritis and absence of other deformity of the lower extremity or bone disease. Only

patients with digital preoperative and postoperative knee radiographs were included. Therefore, 27 patients with no digital knee radiographs were excluded. Six patients with a varus/valgus $>20^\circ$ were also excluded, as the anatomy was too obscured for measurements. A total of 67 knee radiographs from the Asian patients were included for analysis (Figure 1). The 67 Asian patients were matched for age and sex with 67 Caucasian patients who underwent TKA at the Leiden, the Netherlands. The same inclusion and exclusion criteria were applied for the Caucasian patients. Thus, 134 knees with 268 coronal and sagittal plane knee radiographs could be used for anthropometric measurements. The patients' height and weight were obtained from their records.

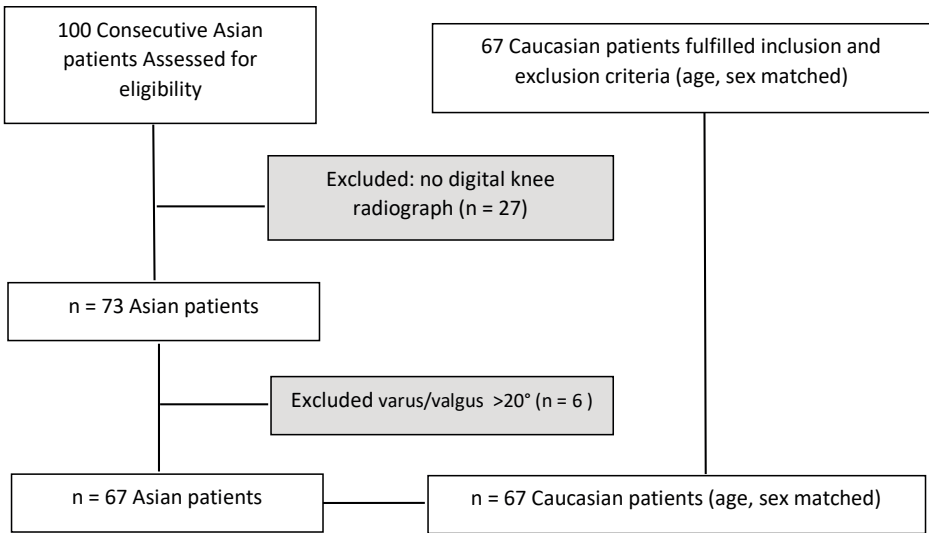


Fig. 1 Flowchart for patient selection

Overall, 57 women (85%) and 10 men (15%) were included in each group. The mean ($\pm$ standard deviation [SD]) ages of the Asian and Caucasian patients were 67 ± 7.8 and 68 ± 7.1 years, respectively. The respective mean body height and body mass index (BMI) were 156 ± 8.0 cm and 29 ± 6.8 kg/m² for the Asian patients and 166 ± 8.1 cm and 30 ± 6.1 kg/m² for the Caucasian patients.

In both hospitals, standing anteroposterior (AP) and supine lateral knee radiographies on short films were performed routinely. All the radiographic measurements were performed on digital radiographs with the PACS software from GE Healthcare (Jakarta, Indonesia) and Sectra (Leiden, the Netherlands). The measurements were performed by 2 authors on all the radiographs of both Asian and Caucasian patients. In all measurements (Figure 2a–2f), a correction for radiograph magnification of 115% was used, according to the roentgen tube-table distance in both hospitals, which was identical. The degree of radiological osteoarthritis (ROA) was classified using the Kellgren and Lawrence (KL)

classification (with 4 being the highest degree of ROA) on the basis of the preoperative AP knee radiographs. The femorotibial angle (FTA, i.e., the lateral angle between the femur and the tibia; Figure 2a), femoral mediolateral (ML) dimension (fML; Figure 2b), and tibial ML dimension (tML; Figure 2c) were measured on the AP radiographs. The femoral AP dimension (fAP; Figure 2d) and tibial AP dimension (tAP; Figure 2e) were measured on the lateral knee radiographs. The distance from the fibular head to the tibial plateau was measured (FiTd; Figure 2f) on the AP radiographs. The patellar tendon length (TL) and patellar bone length (PL) were measured from the lateral radiographs. The ML-to-posterior ratio (i.e., aspect ratios) for the femur (fML/AP) and tibia (tML/AP) and the patella-to-patella tendon ratio (PL/TL) were calculated.

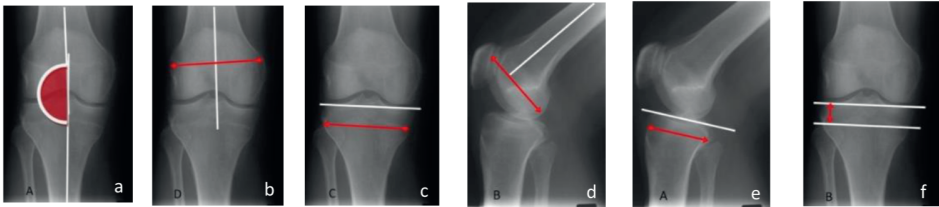


Fig. 2 Radiographic anthropometric knee measurements: (a) femorotibial angle, (b) mediolateral dimension of the femur, (c) mediolateral dimension of the tibia, (d) anteroposterior dimension of the femur, (e) anteroposterior dimension of the tibia, and (f) fibular–tibial distance

The dimensions of the nine different knee implants (Vanguard, Persona Standard, and Persona Narrow from ZimmerBiomet, Warsaw, IN, USA; Genesis II from Smith & Nephew, London, UK; GK Sphere from Medacta, Castel San Pietro, Switzerland; Gemini from Waldemar Link, Hamburg, Germany, and PFC Sigma, Attune Standard, and Attune Narrow from DePuy Synthes, Warsaw, IN, USA) were collected from the manufacturers' brochures.

Statistical analysis

The descriptive statistics for all anthropometric radiological measurements of the knee, age, sex, height, BMI, and degree of ROA (KL score) were recorded. The differences between the groups were analyzed using *t* tests for normally distributed continuous data or the chi-square test for ordinal data (KL). The anatomical measurements of both Asian and Caucasian knees were calculated and compared with the measurements of the type (brand) of knee implant.

RESULTS

The preoperative femoral tibial angle (FTA) in the Asian patients was predominantly varus, whereas that in the Dutch patients was slightly valgus in both men and women

(Table 1). The ROA KL scores were comparable between the two groups: 88% of the KL scores were grades 3 and 4 and 12% were grade 2. The mean femoral and tibial dimensions in the male and female Indonesian Asian and Dutch Caucasian patients and the dimensions of the nine TKA systems were smaller in the Indonesian Asian patients and mismatched with most knee systems of the smaller sizes (Table 2; Figures 3–8).

Table 1 Anthropometric data of the knee (femur and tibia) of Caucasian and Asian patients

	Sex	n	Caucasian	n	Asian	P
FTA (dgr)		67		67		
	M	10	174 ± 5.5	10	183 ± 4.8	0.001
	F	57	178 ± 5.9	57	183 ± 8.2	0.001
fML (mm)		67		67		
	M	10	84 ± 7.1	10	80 ± 9.0	n.s
	F	57	75 ± 7.0	57	70 ± 5.3	<0.0001
fAP (mm)		67		67		
	M	10	66 ± 4.1	10	59 ± 5.6	0.003
	F	57	59 ± 4.3	57	52 ± 4.5	<0.0001
tML (mm)		67		67		
	M	10	76 ± 7.8	10	72 ± 6.8	n.s
	F	57	69 ± 6.2	57	65 ± 5.5	<0.0001
tAP (mm)		67		67		
	M	10	60 ± 2.6	10	51 ± 7.4	0.003
	F	57	51 ± 3.8	57	45 ± 3.6	<0.0001
Aspect ratio fML/fAP		67		67		
	M	10	1.3 ± 0.1	10	1.3 ± 0.1	n.s
	F	57	1.3 ± 0.1	57	1.4 ± 0.1	<0.0001
Aspect ratio tML/tAP		67		67		
	M	10	1.3 ± 0.8	10	1.4 ± 0.1	0.002
	F	57	1.3 ± 0.1	57	1.5 ± 0.1	<0.0001

FTA: femoral tibial angle, tML: tibial mediolateral dimension, fML: femoral mediolateral dimension, tAP: tibial anteroposterior dimension, fAP: femoral anteroposterior dimension, tML/tAP ratio: tibial mediolateral dimension divided the true anteroposterior dimension, fML/fAP ratio: femoral mediolateral dimension divided by the true femoral anteroposterior dimension.

Table 2 Knee anthropometric dimensions of Asian and Caucasian patients and nine total knee arthroplasty systems

	Male Asia		Female Asia		Male Caucasian		Female Caucasian		Vanguard ¹	Genesis II ²	Persona Narrow ³	Persona Standard ¹	GK Sphere ³	Gemini ⁴	Attune Standard ⁵	Attune Narrow ⁵	Sigma RPF ⁵
Tibial dimension Medial Lateral (mm)	72 ± 6.8	65 ± 5.5	76 ± 7.8	69 ± 6.2	75 ± 10.9	73 ± 8.5	72 ± 10.4	72 ± 10.4	73 ± 8.5	74 ± 8.7	73 ± 9.1	73 ± 9.1	73 ± 9.1	73 ± 9.1	73 ± 9.1	73 ± 9.1	73 ± 10.4
Tibia dimension Anterior-Posterior	51 ± 7.4	45 ± 3.6	60 ± 2.6	51 ± 3.8	48 ± 6.8	51 ± 5.7	51 ± 7.98	51 ± 7.98	48 ± 5.7	49 ± 5.6	48 ± 5.8	48 ± 5.8	48 ± 5.8	48 ± 5.8	48 ± 5.8	48 ± 5.8	49 ± 6.7
tML/AP ratio (aspect ratio)	1.4 ± 0.1	1.5 ± 0.1	1.3 ± 0.8	1.3 ± 0.1	1.5 ± 0.01	1.4 ± 0.01	1.4 ± 0.02	1.4 ± 0.02	1.5 ± 0.01	1.5 ± 0.04	1.5 ± 0.01	1.5 ± 0.01	1.5 ± 0.01	1.5 ± 0.01	1.5 ± 0.01	1.5 ± 0.01	1.5 ± 0.01
Femoral dimension Medial Lateral (mm)	80 ± 9.0	70 ± 5.3	84 ± 7.1	75 ± 7.0	70 ± 7.6	68 ± 8.9	63 ± 5.0	70 ± 5.2	68 ± 7.8	67 ± 6.7	67 ± 10.0	67 ± 10.0	67 ± 10.0	67 ± 10.0	67 ± 10.0	67 ± 10.0	67 ± 8.6
Femoral dimension Anterior-Posterior	59 ± 5.6	52 ± 4.5	66 ± 4.1	59 ± 4.3	65 ± 7.1	60 ± 9.6	58 ± 6.9	64 ± 6.9	65 ± 7.8	61 ± 6.5	62 ± 9.6	62 ± 9.6	62 ± 9.6	62 ± 9.6	62 ± 9.6	62 ± 9.6	62 ± 9.0
fML/AP ratio (aspect ratio)	1.3 ± 0.1	1.4 ± 0.1	1.3 ± 0.1	1.3 ± 0.1	1.1 ± 0.01	1.1 ± 0.03	1.1 ± 0.04	1.1 ± 0.05	1.0 ± 0.01	1.1 ± 0.04	1.1 ± 0.03	1.1 ± 0.03	1.1 ± 0.04	1.1 ± 0.04	1.1 ± 0.01	1.1 ± 0.01	1.1 ± 0.01

Values are presented as mean ± standard deviation (in millimeters)

^aZimmerBiomet; ^bSmith & Nephew; ^cMedacta; ^dValdemar Link; ^eDePuy

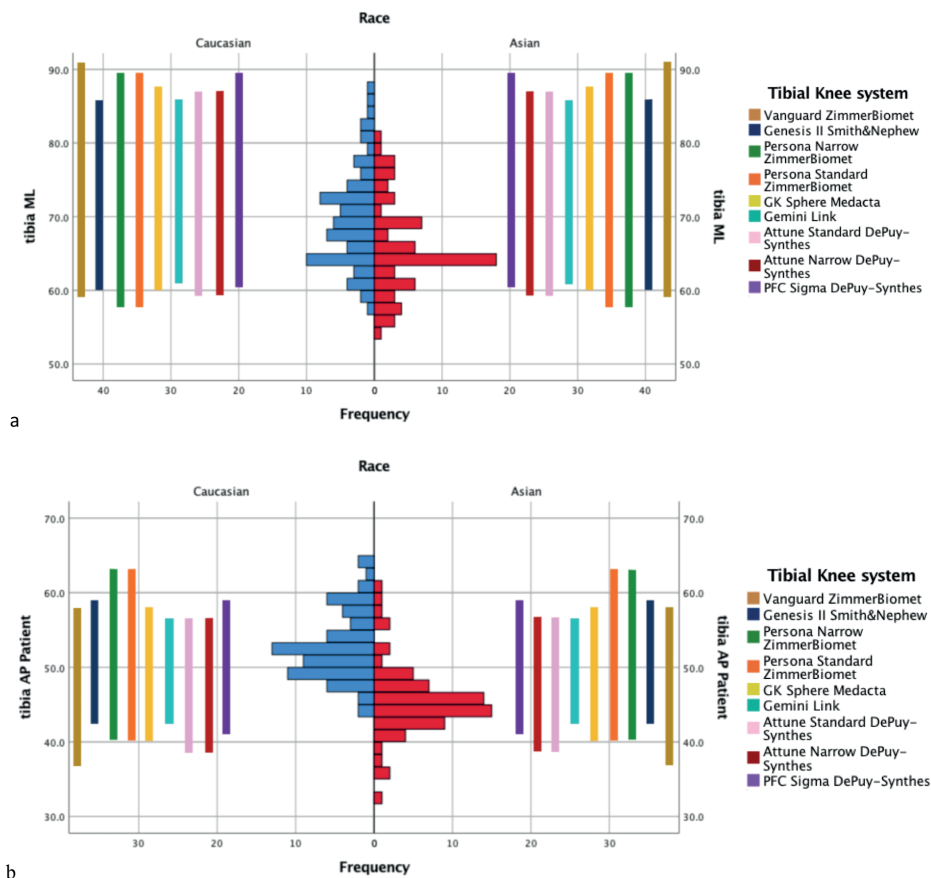


Fig. 3 Anthropometric dimensions of the tibia and matching with nine total knee arthroplasty systems: (a) mediolateral (ML) and (b) anteroposterior (AP)

Femoral anthropometric measurements

The Caucasian femur was larger in both the AP and ML dimensions (Table 2; Figure 4a and 4b) of both males and females. The mean difference in the AP dimensions of the femur between the Caucasians and Asians was 6.6 mm; this was not corrected for the difference in height. The female patients had smaller AP and ML femoral widths (i.e., narrower femoral condyles) than the male patients among both the Asian and Caucasian patients (Table 2). In terms of ML dimension, the Caucasian distal femur was, on average, 6 mm larger than the Asian distal femur (Figure 4). The mean ML/AP aspect ratio of the femur (Table 2; Figure 7) in the Asian patients was larger than that in Caucasians, but the difference was insignificant. The mean fibular–tibial distance (FiTd; Figure 2f) was comparable between the two groups: 10 ± 3.0 mm in Asians and 9.8 ± 3.1 mm in Caucasians.

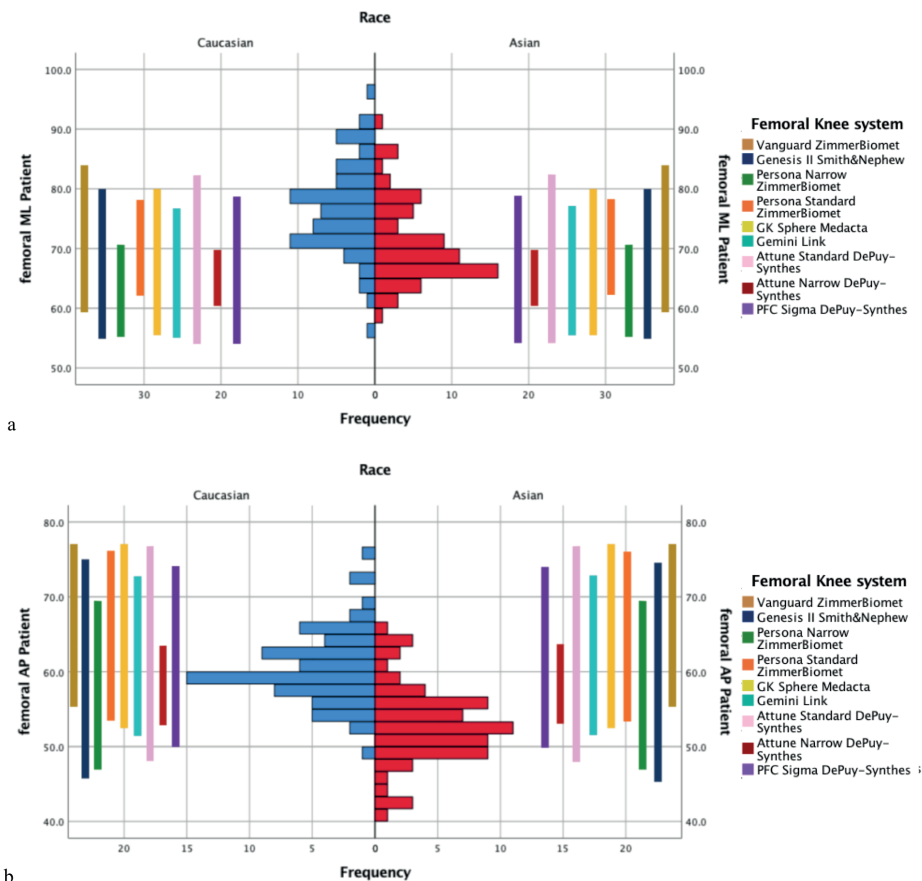


Fig. 4 Anthropometric dimensions of the femur (ML) and matching with nine total knee arthroplasty systems: (a) mediolateral (ML) and (b) anteroposterior (AP)

Tibial anthropometric measurements

The AP and ML tibial dimensions were larger in the Caucasian patients than in the Asian patients (Table 2; Figure 3a and 3b) in both males and females. On average, the ML tibial dimension of Caucasians was 4.3 mm larger than that of Asians. The mean aspect ratio of the tibia (Table 2) was larger in the Asian patients than in the Caucasian patients for both male and female patients (Figure 5).

Comparison of the dimensions of the nine different TKA systems with the anthropometric data

The largest ML dimensions of the proximal tibia in both populations could be accommodated by all nine TKA systems. However, the smallest ML dimension of the proximal tibia in the Asian patients could not be matched with any of the nine TKA systems (Figure 3a). The largest AP dimension of the proximal tibia in the Caucasian patients could not

be matched with any of the nine TKA systems. Only the Persona Standard and Persona Narrow TKA systems matched with the largest AP dimension of the proximal tibia in the Asian patients. As for the smallest AP knee implant dimension, all nine TKA systems could be matched with the smallest dimensions of the Caucasian knees, but none of the nine TKA systems matched with the smallest Asian knees (Figure 3b).

With respect to the distal femoral implant dimensions, none of the nine TKA systems matched with the largest ML dimension of the distal femur of both the Asian and Caucasian patients. Most of the nine TKA systems matched with the smallest ML dimension of the distal femur of both populations (Figure 4a). Most of the nine TKA systems matched with the largest AP dimension of the distal femur of the Caucasian (except for Persona Narrow and Attune Narrow) and Asian populations (except for Attune Narrow). None of the nine TKA systems matched with the smallest AP dimension of the distal femur of the Asian patients, whereas most of the nine TKA systems could be matched with the Caucasian knees (Figure 4b).

The tibial aspect ratios (ML/AP) of the knee implants showed that the knee systems had a smaller AP diameter for the same ML diameter (Figure 6). As for the femoral aspect ratios of the femur in both Asian and Caucasian knees, all nine knee systems had a smaller ratio than the patients' anthropometry (Figure 8).

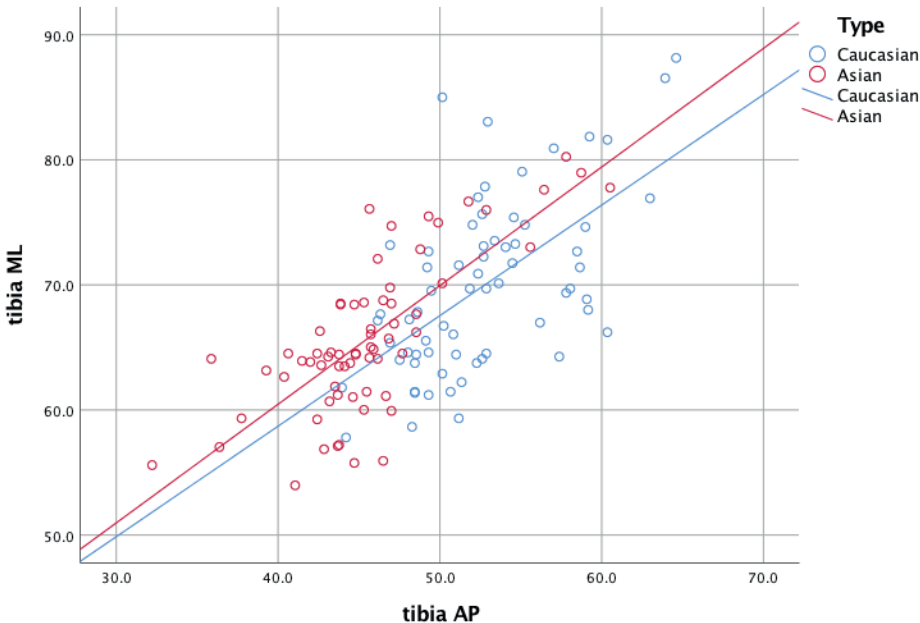


Fig. 5 Comparison of the tibial dimension between Asian and Caucasian patients

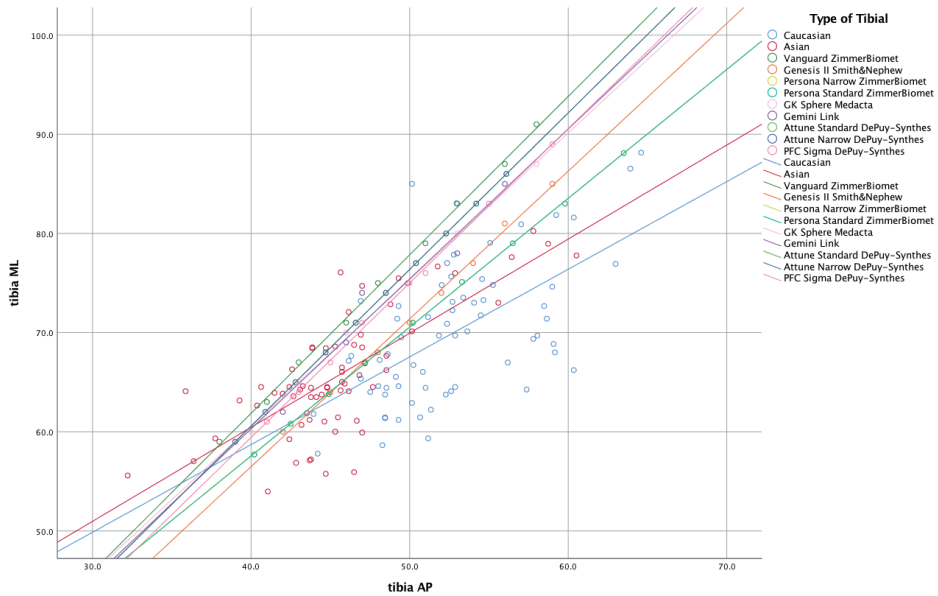


Fig. 6 Comparison of the tibial dimension among Asian knees, Caucasian knees, and nine total knee arthroplasty systems

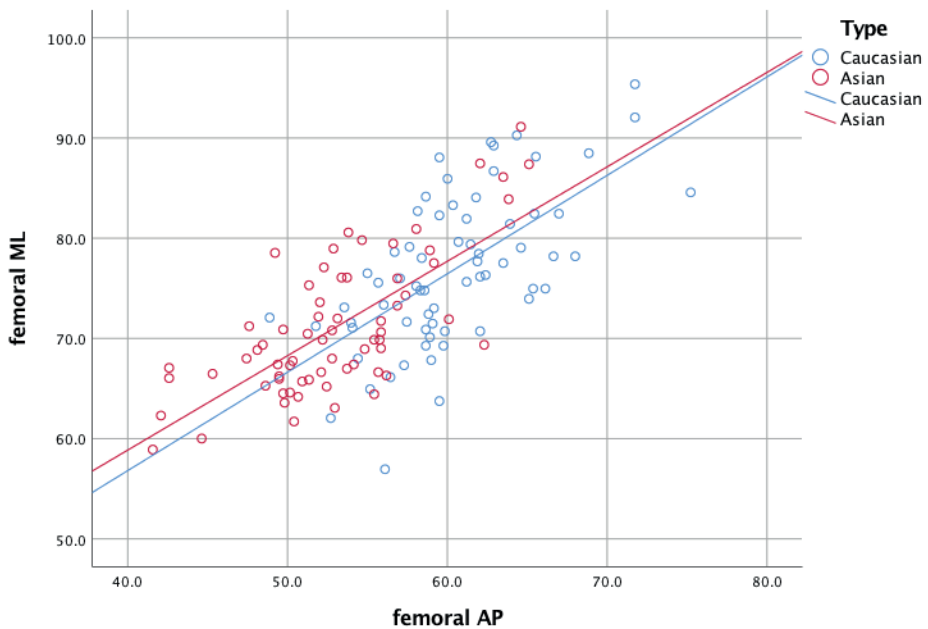


Fig. 7 Comparison of the femoral dimension between Asian and Caucasian patients

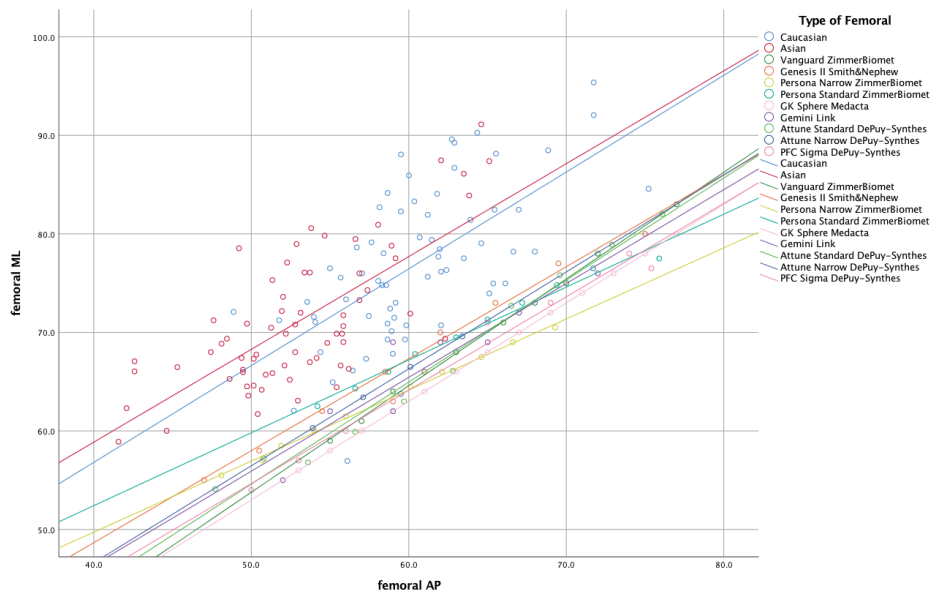


Fig. 8 Comparison of the femoral dimensions among Asian knees, Caucasian knees, and nine total knee arthroplasty systems

Patella dimensions

The mean length of the patellar bone (lateral knee radiograph) was 39 ± 4.3 mm in Asians and 40 ± 4.1 mm in Caucasians. The mean patellar tendon length was 42 ± 5.1 mm in Asians and 52 ± 7.2 mm in Caucasians ($p = 0.005$). The mean Insall-Salvati index was 1.1 ± 0.15 in Asians and 1.3 ± 0.21 in Caucasians ($p = 0.001$); thus, the Asian patients had patella baja relative to the Caucasians patients.

DISCUSSION

The most important finding of the present study was that the Asian patients had knees with smaller AP and ML dimensions of both the distal femur and proximal tibia. Overall, the smallest sizes in the Asian patients could not be matched with any of the nine knee systems. The Asian patients were, on average, 6% shorter than the Caucasian patients and had smaller distal femoral and proximal tibial dimensions. This suggests that to have an optimal fit, the knee systems should be available in a wider range of sizes (i.e., more smaller sizes) in accordance with the findings from an earlier study.¹⁵ However, Asian knees also have a wide range of dimensions, with even higher ML/AP ratios than Caucasian knees. This stresses that differences in knee shape between the two groups exist, which is supported by an earlier study.⁴¹ Nevertheless, it also underscores that a mismatch is created when the total knee prosthesis design is based only on a small

range of Caucasians. Long-term success of TKA depends on an optimal match between the prosthesis and the resected bone. Therefore, different dimensions of knee design should be used in Asian patients to optimize the biomechanical performance of the artificial knee joint. Furthermore, the female knee tends to be smaller in width than the male knee, which is consistent with the results of other published studies.^{17,18,29} In addition to implant fit, functional knee phenotypes also have an impact on knee outcome, as implant alignment affects intraoperative bone resection. Therefore, they will influence the patients' AP and ML distal femoral and proximal tibial dimensions, implant size, and implant–bone fit during TKA.¹⁴ When mechanical alignment in the restricted kinematic alignment phenotype is used, the medial or lateral compartment might increase even in a normosized component. It will also cause excessive tension on the capsule and ligaments, which may eventually lead to the stiffening of the knee or unexplained postoperative knee pain.

The mean ranges of the FiTd were 8–11 and 9–12 mm for the Caucasians and Asians, respectively, which were comparable. However, because the smallest tibial component could not fit the smallest Asian knee, resecting part of the fibular head would be necessary to accommodate the much bigger tibial component.³² Similar to the findings of our study, Havet et al. also found no association between FiTd and height.¹³ With regard to the relative patella baja in the Asian patients as compared with the Caucasian patients, this should be taken into account when bone resections are planned during TKA.

The Asian knee has a slightly varus alignment^{1,16,33} with a limited range of motion preoperative and more severe varus and flexion contractures.⁸ Therefore, more extensive soft tissue release of the posterior capsule is often required, necessitating the use of a larger AP dimension with a certain ML femoral dimension of the knee implant. We found that most knee systems did not accommodate the smallest Asian knee sizes; thus, a good ML fit of the femoral implant will either have an anterior overhang or cause overstuffing of the knee joint. Meanwhile, a good AP fit of the implant may cause undersizing of the ML dimension, thereby avoiding both anterior notching and overstuffing. These mismatches were also found in Korean, Japanese, and Brazilian patient groups.^{21,22,36} A mismatch between a knee implant and anatomy (e.g., overhang) may cause complaints, whereas a mismatch with the tibial component may cause more symptoms than the femoral components.^{11,17,25,27,40} Surgeons have to decide whether to select bigger or smaller components when the implant tibial component and the resected proximal side of the tibia are mismatched, which in turn will result in either overhanging and underhanging, respectively.³⁹ An overhang of either the femur or the tibia might increase capsular tension and ultimately lead to overvolumizing. This will increase joint pressure and cause pain and stiffness of the knee.^{25,26} The overhang also causes popliteal impingement of either the femur or the tibia. Even in cases of normosized implants, popliteal impingement can still be found, especially in oversized implants or in case

of posterolateral overhanging due to rotation of the tibial component. Either way, this causes knee pain and stiffening.³ Overhanging of the tibial component, on the medial side, causes stress on the soft tissues that envelop during range of motion movements, which also results in persistent knee pain after TKA. Furthermore, overstuffing the knee with an implant will also cause excessive tension on the capsule and ligaments, which may lead to knee stiffening or postoperative knee pain.⁷ In contrast to oversizing, undersizing the tibial component may eventually lead to earlier mechanical loosening of the bone–implant interface due to the overload of the trabecular bone.² Considering the problems associated with both oversizing and undersizing of the tibial component of the knee implants, a good implant fit is important because a mismatch between the knee bone and implant will lead to early loosening, pain, and subsequent revision.

As for the femoral component, an anterior overhang of the femoral implant might cause patella overstuffing, which increases the patellofemoral forces; in turn, these might disturb the extensor mechanism and limit knee flexion.^{17,30} Besides the difference in implant size, the native femur also has a different shape (more trapezoidal) as compared with the TKA systems. This difference in shape might cause an anterior overhang or overstuffing.⁴ Usually, to avoid anterior overstuffing, some surgeons prefer to undersize. The femoral implant shape becomes important and worth considering when choosing TKA systems. Another consideration to avoid a femoral implant mismatch is the surgical technique. Hence, if the external rotation of the femoral component is too much ($\geq 5^\circ$), an overhang can be created, even in normosized femoral components.^{5,34} The femoral component should not be externally rotated by $>3^\circ$ unless the extensive valgus has been released. Thus, to obtain the best fit for Asian femoral condyles, the patients' knee phenotypes and preoperative measurements, the characteristics of each TKA system and sizing, and intraoperative remeasurements are required not only to avoid underhang or overhang but also to gain optimal flexion-extension (AP length) and soft tissue tensioning (ML width). Preoperative templating is important for guidance on the most optimal fit, although a slight discrepancy with the actual size might be present during surgery. Even a preoperative computed tomography (CT) or magnetic resonance imaging (MRI) scan will not solve this problem, as intraoperative findings can lead to changes in preoperative plans, especially in more severely deformed knees (e.g., varus or valgus, osteophytes).

The Asian tibia tended to be narrower in ML width than the tibial components of the nine TKA systems for a given AP size. In a previous study, Bonnin et al. found that only 17% of patients have similar medial and lateral tibial plateau sizes and most had smaller lateral plateaus. For this reason, either asymmetrical plateaus are preferred or the component is rotated.⁶ Three systems had an asymmetrical tibial component design: the Persona Standard and Persona Narrow knee designs (ZimmerBiomet) and the Genesis II TKA system (Smith & Nephew). However, even these asymmetrical plateaus may cause overhang if

the smallest size does not accommodate the smallest knee morphological phenotype. Technically, the tibial baseplate should be aligned by referencing with respect to the anterior tibial tuberosity, thus externally rotating to the posterior margin. This will cause loss of coverage on the medial side and some overhang on the posterolateral side if the component is too big. Even in normosized implants, tibial baseplate positioning causes posterolateral overhang that should be avoided. Therefore, the surgical technique and implant sizing also play important roles in avoiding overhang.

The ML/AP aspect ratios of the distal femur in both patient groups were larger than those of all nine knee systems. This implies that all nine knee systems minimize overstuffing of the joint. As for the proximal tibia, most of these tibial component knee implants are larger than the anthropometric tibia ML/AP aspect ratios. It is interesting that some implants have similar ML diameters but smaller AP diameters, whereas others have larger AP diameters with the same ML diameter.

This study has some limitations. First, although 268 coronal and sagittal radiographs were used in the measurements, the sample size might be too small, which might have caused a type II error. So, increasing the number of measurements in a larger cohort will increase external validity of our findings. Nevertheless, our results indicate that differences existed between the different patient groups, emphasizing the importance of preoperative templating. Thus, a specific implant can be selected for a specific knee. A larger study group would most probably underscore this, thus reducing the possibility of a type II error. Second, we used routine radiographs to assess the anthropometric morphology of the knees of both patient groups. Although CT and MRI scans will indeed provide more information on the real morphological dimensions, templating of knee implants on radiographs reflects daily clinical practice. The intraclass correlation coefficient of the interobserver variability in this study was high at 0.853 (good reliability) for the tibial measurements and 0.776 (good reliability) for the femoral measurements. The latter has been reported in other studies as well.^{10,12,35} Finally, only nine knee implant systems were used for comparison with the anthropometric measurements of the two patient groups.

With the results of this study, surgeons might predict and learn to match the implant type and size on the basis of patient sex and ethnicity. Different TKA techniques should also be used according to the patient's anthropometry and knee phenotypes.

CONCLUSION

Absolute and relative differences in knee dimensions exist not only between Asian and Caucasian knees but also within both groups. Although Indonesian Asian patients are smaller, variations within the same ethnic group exist; furthermore, small Dutch phenotype and tall Indonesian phenotype exist and vice versa. As different phenotypes

exist, an increase in the range of available knee component sizes will be beneficial for patients. Extending the range of the tibial and femoral components with one to two smaller sizes in all dimensions for the Asian populations will increase the range of optimal fit. Therefore, considering ethnicity and sex is important when planning TKA and selecting the optimal fit to the joint. Increases in current implant sizes (one size larger and one size smaller) will accommodate a better fit to the different human phenotypes. As three-dimensional printing facilities for acetabular implants components are becoming increasingly available, the same might happen for the tibial and possibly the femoral components of a total knee system. Patient-specific printed implants based on preoperative scans or statistical shapes will create implants with the most optimal fit. However, the surgical technique to position and place the implant will still be an important issue, also with robotic placement. In the end, TKA remains a compromise to nature.

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Chapter 3

**A comparison of clinical and patient
recorded outcomes of TKR in Asian
versus North American patients**

Budhiparama N.C.
Gaudiani M.A.
White P.B.
Satalich J.
Nelissen R.G..
Ranawat A.S.
Ranawat C.S.

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ABSTRACT

Background. Cultural differences between continents may also affect the outcome on interventions. This study compared an Asian and North American cohort of total knee replacement (TKR) patients.

Questions/purposes. This study aims to compare the patient-reported outcome measures as well as a functional outcome after TKR between these two different patient populations with a different cultural societal background in two different countries.

Patients and Methods. A retrospective study on two cohorts of 76 Asian TKR patients and 64 North American TKR patients were compared. Demographics, patient-reported outcome measures (Knee Society Score (KSS), Patient-Administered Questionnaire (PAQ), and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)), knee range of motion (ROM), and radiographic component position were compared.

Results. The Asian cohort had more females compared to the North American and significantly worse preoperative ROM, and worse KSS function score and PAQ pain scores. The preoperative KSS knee score and WOMAC scores were comparable between the two groups. Postoperatively, the differences in WOMAC and KSS knee scores were significant, while KSS function and PAQ were comparable between groups.

Conclusions. Even though Asian TKR patients had significantly worse preoperative scores, their postoperative outcomes were comparable to North Americans. The higher preoperative functional deficit and the higher pain levels in the Asian population might be due to cultural differences and/or socioeconomic reasons, which made Asian patients present with more severe conditions in the preoperative consultation for a possible surgical treatment compared to North Americans. More research is needed to investigate the difference between these cultural impacts on TKR outcomes.

INTRODUCTION

Osteoarthritis (OA) is a common cause of debilitating knee pain. Total knee replacement has emerged as an effective treatment for osteoarthritis of the knee. Clinical outcomes have been positive and total knee replacements are now performed worldwide.¹⁻³ Previous studies have examined the outcomes and compared the results across different Western countries, such as the Sweden, The Netherlands, United States, United Kingdom, and Australia.⁴⁻⁷ The variation of patients preoperatively has been thought to be a result of different health care systems and access. However, these populations are largely Caucasian, living in comparable societies with presumably similar stresses on their knees during daily living. There has not been a comparison of total knee clinical outcomes between a Western population and an Asian population who live in their continent with their specific societal surroundings, which will also have an impact on the lower extremity and more specifically, knee use.

Asian populations have different cultural practices than Western populations and have been found to have a higher prevalence of tibiofemoral OA when compared to Caucasian subjects.^{8,9} Studies suggest that the cause is due to squatting, which is common among Asian populations. Squatting requires a high degree of knee flexion and five to six times more tibiofemoral contact forces than bodyweight. It has been found that the tibiofemoral reaction forces from posterior direction to anterior happens rapidly when squatting and those have significant long-term effects on the joint cartilage.¹⁰ These effects could result in variations between Western and Asian populations both at the preoperative and at the postoperative state.

There is also an average size difference between Asian and Caucasian populations. Morphometric analyses have found that typically an Asian knee is smaller than a Caucasian knee.¹¹⁻¹³ These factors could contribute to different clinical outcomes between an Asian and a Caucasian population in its relations with implant design^{14,15} and warrants more research.

In addition to the morphological differences, there are large socioeconomic differences between certain Asian and North American populations. For example, the World Bank classifies the United States as a “high income” country and Indonesia as “lower middle income”.¹⁶ Socioeconomic factors have been found to contribute to different preoperative status in various ethnic groups.¹⁷

We aim to compare the clinical and patient-reported outcome measures (PROM) and postoperative radiographic measurements between the two patient cohorts. Our first objective was to assess the variation in clinical and PROM of TKR between these two populations. The second objective was to identify what factors influence the variation in clinical and PROM between the two populations.

MATERIAL AND METHODS

A retrospective analysis of two institutional review board approved registries of patients with TKRs at two institutions between 2007 and 2014. One institution was located in Indonesia and has a patient base that is primarily of Chinese, Malay, or Indian ethnic backgrounds, whereas the other location was located in the United States with a patient base majority of Caucasian. To prevent confounding data due to knee implant design, the same implant was studied between the Asian and Caucasian cohorts. The inclusion criteria were patients with OA who underwent primary TKR using the PFC Sigma rotating platform with high flexion posterior stabilized design (DePuy Synthes, Warsaw, Indiana, USA). The exclusion criteria were patients with revision TKR and patients with periprosthetic joint infection. Thus, 76 TKRs from the Indonesia Institution and 64 from the United States Institution could be included. None of the patients were lost to follow-up. The follow-up averaged between 4.27 years and 4.40 years for the Asian and North American cohorts, respectively.

Two fellowship trained, high-volume, arthroplasty specialists performed all TKRs, using similar gap-balancing techniques. Both surgeons used similar pain protocols, which included an intraarticular injection, and both cohorts of patients went home with the same rehabilitation protocols after surgery. All patients were matched for age and body mass index (BMI).

All patients had clinical findings recorded preoperatively and at their latest annual follow-up. Clinical findings included range of motion (ROM) as measured by a goniometer by one of the two senior authors. Flexion values, as well as the presence of flexion contractures, were measured at each follow-up appointment. Full ROM was defined as flexion values minus the degree of the flexion contracture. Pain and function were assessed preoperatively and at the last follow-up using both the knee society pain and function scores (KSS, a higher score indicates better function), as well as the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC, a lower score indicates better function). Additionally, a patient administered questionnaire (PAQ) was utilized to assess patient satisfaction, pain, and difficulty performing flexion-based activities, including kneeling, negotiating stairs, squatting, and sitting on heels.¹⁸ The pain domain portion of the PAQ was reported separately (a higher score indicates more pain).

Anteroposterior (AP) and lateral knee radiographs were collected at the last follow-up at both institutions. AP femoral flexion, AP tibial angles, lateral femoral flexion, and lateral tibial angles were calculated with the same technique to assess component positioning and alignment in the coronal and sagittal planes. This technique was previously described in Gromov et al.¹⁹

Statistics were primarily descriptive with means and standard deviations calculated for continuous variables; frequencies and percentages were calculated for discrete

variables. Comparison between cases and controls was made using independent t-test. Significance was set at a p-value <0.05. Analyses were performed using SPSS version 25.

RESULTS

Preoperative patient demographics are found in Table 1. No significant difference in demographic data between Asian and North American patients were seen. The mean age for Asian and North American were 68.85 ± 3.90 years and 70.02 ± 5.29 years respectively with no significant difference ($p=0.107$). The mean BMI for Asian and North American was 27.46 ± 3.58 and 28.40 ± 4.41 respectively with no significant difference ($p=0.276$). Preoperative clinical scores showed the Asian cohort had significantly lower scores than North American patients for both KSS function score (54.34 ± 12.00 vs. 61.79 ± 18.63 ; $p=0.006$) and knee ROM (103.88 ± 19.41 vs. 111.17 ± 13.11 ; $p=0.016$). Compared to the American cohort, the Asian patients also had significantly higher (i.e. more pain) preoperative PAQ pain scores (18.4 ± 4.3 vs. 16.1 ± 2.0 ; $p=0.001$) but better for total PAQ score (65.15 ± 10.58 vs. 74.01 ± 16.90 ; $p=0.0001$). No significant difference between Asian and North American for KSS Knee Score (53.40 ± 14.55 and 55.67 ± 14.10 respectively; $p=0.266$) and WOMAC Score (70.25 ± 7.55 and 68.56 ± 11.53 respectively; $p=0.173$).

Postoperatively, the Asian cohort had a slightly lower KSS Knee score (93.18 points ± 4.72 vs. 96.50 points ± 4.64 ; $p=0.0001$) but better WOMAC scores (33.36 ± 10.11 vs. 37.90 ± 12.71 ; $p=0.021$) compared to North American TKR patients. The postoperative range of motion of the knee ($p=0.661$), KSS function score ($p=0.441$), and total PAQ score ($p=0.335$) were comparable between the two cohorts (Table 2).

The postoperative mean femorotibial angle was $184.9^\circ \pm 1.09$ for the Asian TKR patients and $184.2^\circ \pm 2.82$ for the North American TKR ($p=0.133$). Position of the TKR as measured at radiographs, showed that the mean AP femoral component angle of the TKR in the Asian cohort was $95.6^\circ \pm 1.19$ and the North American $94.4^\circ \pm 2.28^\circ$ ($p<0.0001$). The mean AP tibial angle in Asian knees was $89.3^\circ \pm 1.1^\circ$ and the North Americans TKR $89.8^\circ \pm 2.1^\circ$ ($p=0.051$). On the lateral radiographs, TKR positions were different as well, the Asian cohort had less lateral femoral flexion position than the North American TKRs ($8.3^\circ \pm 3.02^\circ$ vs. $14.9^\circ \pm 3.74^\circ$; $p<0.0001$); the lateral tibial slope angle was slightly higher in the Asian TKRs compared to the North American TKRs ($86.0^\circ \pm 2.12^\circ$ vs. $90.8^\circ \pm 3.2^\circ$; $p<0.0001$).

Table 1. Preoperative patient characteristics

	Asian		North American		p-value
	Mean	Std	Mean	Std	
Age (years)	68.85	3.90	70.02	5.29	0.107
BMI	27.46	3.58	28.40	4.41	0.2763
Follow up	4.27	1.29	4.40	0.63	0.763

SD: standard deviation; BMI: body mass index

Table 2. Clinical and patient recorded outcome scores comparing Asian with North American patients.

	Pre-op					Post-op				
	Asian		North American		P-value	Asian		North American		P-value
	Mean	Std	Mean	Std		Mean	Std	Mean	Std	
Range of Motion (°)	103.88	19.41	111.17	13.11	0.016	123.94	11.35	124.42	10.55	0.661
Knee Society Knee score ^a	53.40	14.55	55.67	14.10	0.266	93.18	4.72	96.50	4.64	0.000
Knee Society Function score ^a	54.34	12.00	61.79	18.63	0.006	97.23	3.50	93.75	11.81	0.441
WOMAC ^b	70.25	7.55	68.56	11.53	0.173	33.36	10.11	37.90	12.71	0.021
PAQ ^b	65.15	10.58	74.01	16.90	0.000	20.05	14.04	26.89	22.95	0.335
PAQ Pain Score ^b	18.4	4.3	16.1	4.3	0.0009	11.3	2.0	11.7	2.7	0.2936

SD: standard deviation; WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index; PAQ: Patient-Administered Questionnaire

^a higher scores are better

^b lower scores are better

Table 3. Comparison of post-operative TKR position at AP and Lateral Radiographs in the two cohorts

Degree	Asian TKR position	North American TKR	P-value
AP Femoral component Angle ^a	95.6 ± 1.2°	94.4 ± 2.3°	<0.000
AP Tibial component Angle ^a	89.3 ± 1.1°	89.8 ± 2.1°	0.06
AP Femorotibial Angle ^b	184.9 ± 1.2°	184.1 ± 3.4°	0.04
Lateral radiograph Femoral component position ^c	8.3 ± 3.0°	14.9 ± 3.7°	<0.0001
Lateral radiograph Tibial slope ^d	86.0 ± 2.1°	90.8 ± 3.2°	<0.0001

TKR: total knee replacement; AP: anteroposterior

^a>90° are in valgus, <90° are in varus

^b>180° is valgus

^cLarger value indicates more component flexion versus extension

^d<90° more posterior slope

DISCUSSION

Both the Asian and North American cohort had an improvement in postoperative range of motion, function and pain scores. Interestingly, despite a lower preoperative range of motion of the knees in the Asian patients, postoperatively, there was no significant difference between the two patient populations. This is interesting because preoperative range of motion is found in multiple studies to be an important determinant of postoperative range of motion, which is again associated with overall patient satisfaction and functional level.²⁰⁻²⁵ Asian patients with the same TKR design as the North American population had a larger improvement of postoperative range of motion of knees despite a worse ROM preoperatively. This is caused by either implant position and/or postoperative rehabilitation. The femoral component was in 7 degrees more flexion position in North American knees, while the tibial component was in about 4 degrees more posterior tilt, thus these component positions seemed not to be a major cause for the better postoperative ROM improvement in Asian TKR. With respect to rehabilitation, both hospitals started with a protocol of immediate postoperative ROM exercises and ambulation. A possible difference in the Asian and the Caucasian patients is that the former needs hyperflexion for daily life, either for squatting or for praying position (i.e. Moslem). These cultural differences in knee use are most probably related to the better functional recovery of the knees in Asian patients. The significant improvement in postoperative KSS pain score, KSS functional score, and WOMAC score were found in Asian cohort especially in WOMAC pain night in bed, pain sitting, pain standing, AM and PM stiffness, rising from sitting, standing, bending WOMAC, and on/off WOMAC. The most important is KSS functional and WOMAC pain sitting and standing, and AM and PM stiffness, since we know that Asian people have many cultural and religious activities that require improvement of those functions. Although other factors such as obesity also influence postoperative range of motion, the BMI was comparable between both cohorts.

Our results are in contrast with another study using the same mobile bearing high flexion design (Sigma RPF) which concluded that preoperative flexion and the design of the knee prosthesis were the predominant factors of postoperative flexion.²⁶ But that study was most likely done in Caucasians. Another previous study also found that preoperative flexion played a significant role in the postoperative gain in flexion and not the type of prosthesis.²⁷ These results have been found for more than two decades by others.^{17,25-28} Furthermore, our results also indicate that for North American and Asian patients, despite the various differences in knee morphology, preoperative deformity, and postoperative use in daily life, the implant provides comparable postoperative outcomes in both patient cohorts.

In our study, we found a slightly worse, preoperative WOMAC score for Asian compared to North American, and a higher PAQ pain scores (i.e. more pain). The latter might reflect

cultural and social differences between these countries. In Asian cohort, it is possible that socioeconomic status is associated with delayed healthcare, with a subsequent worse osteoarthritis stage at presentation for treatment. Although this research was done in a private hospital in Indonesia, the insurance coverage, both from national health care and private do not fully cover the surgery expenses. This economic shortcoming causes patients to delay getting their surgeries. Despite this, the postoperative patient reported scores were comparable between these two groups and even slightly better (i.e. KSS knee, WOMAC, overall PAQ) for the Asian patients. The overall PAQ (i.e. patient satisfaction, flexion-based activities including kneeling, negotiating stairs, squatting and sitting on heels) was 30% better in Asians (20 vs. 27 points in North Americans), but did not reach significance.

A study from Singapore among different ethnicities, did also found no statistical difference in outcome measures for TKR of different ethnic groups.²⁴ The difference between that study and ours is most likely the result of the different patient ethnicities within different social settings (Indonesia and US) in contrast to different patient ethnicities (Malay, Chinese and Indian) within the same social setting (Singapore).

Preoperative PAQ Pain score in Asian cohort was significantly higher than in North American. Based on a previous study by Mengelson et al,²⁹ pain is a major determinant for outcome of TKA among women, and different perceptions of pain are noted in various ethnic groups, thus ethnicity should be considered as a covariate in evaluating TKA outcomes. Nevertheless, Asian patients had higher postoperative KSS knee score and WOMAC outcome scores.

Preoperative clinical score comparison between these two cohorts showed slightly but significantly worse scores (i.e. in ROM, KSS function score and PAQ pain score) in Asian cohort compared to the North American. These results supported a previous study conducted across Europe, Canada, the United States, UK, and Australia for outcome of total knee replacement, which showed a wide range of preoperative scores across these countries.^{4,5} The authors attributed the worse WOMAC scores and knee function to the long waiting times in the UK compared to other countries as well as to cultural differences. Gossec et al comparing almost 2000 patients, found high preoperative pain levels mainly in Canada, with lower pain levels in most European countries.⁵ For that matter, the severity of the preoperative pain level is considered by most surgeons to be the major determinant to indicate a total knee replacement, in presence of at least moderate radiological osteoarthritis and old age.⁷

It has been reported that ethnic minorities in the US are less likely to consider TKR, due to limited health care access, cultural and socio-economic factors such as familiarity, and cost.¹⁷ Such social differences are seldom mentioned in articles but are a major driver when indicating and performing elective arthroplasty surgery. For that matter, comparing results between countries can be severely biased, health care access differ-

ences are present in the Netherlands, which has a solidarity system of private health insurance.⁶ Reliance on natural remedies, religious beliefs, and fear of surgery are also additional factors, which have been found to influence the decision to engage in TKR. We presume a variety of these reasons cause a delay in presentation in Asian patients, which explained why Asian patients had lower function score, worse ROM, and higher patient pain scores preoperatively.

Postoperative outcome scores were clinically comparable even after controlling for confounding variables. Our results mirror other studies in finding that geographic location alone does not dictate outcome scores,¹ despite differences in socio-economic environment.⁶ However, in a study examining outcomes in the United States, the United Kingdom, and Australia, patients in the United Kingdom had lower postoperative functional scores even after controlling for confounding variables.⁴ They were not able to determine an exact cause, but noted that WOMAC pain scores were similar for all countries. While there is little data comparing an Asian country versus a North American one, we believe our results agree with other studies and show that location is not a factor in TKR outcomes, despite perceived differences with respect to daily use of the lower extremity in Asian and Caucasian patients.

As for component position, AP femoral and tibial component measurements were statistically different between the two groups. On the lateral view, the Asian patients had less femoral flexion and more posterior tibial slope in comparison to the North American patients, despite the use of similar intraoperative guiding systems. These differences in sagittal plane alignment between countries are interesting and potentially indicative of the previously described morphological differences between Asian and non-Asian patients. However, post-operative, and change in range of motion values were not significant between the two cohorts. More research is needed to explain these differences. This study has certain limitations. First, all surgeries were performed by two specialized knee surgeons in specialized arthroplasty centers. Therefore, the postoperative outcome scores can be partially overestimated when extrapolated to the general TKR population. Secondly, only patients with the Sigma RPF knee were used to eliminate prosthesis difference on the outcome between these two cohorts. Thirdly, the North American population had a wide variety of ethnic groups and both cohorts did not have detailed ethnic and socioeconomic demographic data. We assume both cohorts are similar demographically to the city and country they reside in, the North American cohort was based in a major American metropolitan city and the Asian came from a major Indonesian metropolitan city. The North American demographic data shows the majority to be Caucasian. Finally, although preoperative outcome score data and range of motion data were collected prospectively, this is a retrospective study and as such unknown confounders could not be corrected for.

CONCLUSIONS

Asian patients had significantly worse preoperative outcome scores, both on the pain score, function score, and knee range of motion but post-operative outcome results were slightly better for the Asian patients compared to the North American counterpart. Cultural and societal differences (i.e. health care access) may be drivers in both the pre-operative presentation as well as the postoperative perception of outcome (i.e. patient reported outcome) as well as function (i.e. the need for a knee to high flex during social activities). Both aspects, cultural and social should be taken into account when comparing outcome of elective arthroplasties between different countries.

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Chapter

4

**Does circumferential patellar
denervation result in decreased knee
pain and improved patient-reported
outcomes in patients undergoing non-
resurfaced, simultaneous bilateral total
knee arthroplasty?**

Budhiparama N.C.

Hidayat H.

Novito K.

Utomo D.N.

Lumban-Gaol I.

Nelissen R.G.

ABSTRACT

Background. Anterior knee pain, which has a prevalence of 4% to 49% after TKA, may be a cause of patient dissatisfaction after TKA. To limit the occurrence of anterior knee pain, patellar denervation with electrocautery has been proposed. However, studies have disagreed as to the efficacy of this procedure.

Questions/purposes. We evaluated patients undergoing bilateral simultaneous TKA procedures without patellar resurfacing to ask: (1) Does circumferential patellar cauterization decrease anterior knee pain (Kujala score) postoperatively compared with non-cauterization of the patella? (2) Does circumferential patellar cauterization result in better functional outcomes based on patient report (VAS score, Oxford knee score, and Knee Injury and Osteoarthritis Outcome Score) than non-cauterization of the patella? (3) Is there any difference in the complication rate (infection, patellar maltracking, fracture, venous thromboembolism, or reoperation rate) between cauterized patellae and non-cauterized patellae?

Methods. Seventy-eight patients (156 knees) were included in this prospective, quasi-randomized study, with each patient serving as his or her own control. Patellar cauterization was always performed on the right knee during simultaneous, bilateral TKA. Five patients (6%) were lost to follow-up before the 2-year minimum follow-up interval. A single surgeon performed all TKAs using the same type of implant, and osteophyte excision was performed in all patellae, which were left unresurfaced. Patellar cauterization was performed at 2 mm to 3 mm deep and approximately 5 mm circumferentially away from the patellar rim. The preoperative femorotibial angle and degree of osteoarthritis (according to the Kellgren-Lawrence grading system) were measured. Restoration of the patellofemoral joint was assessed using the anterior condylar ratio. Clinical outcomes, consisting of clinician-reported outcomes (ROM and Kujala score) and patient-reported outcomes (VAS pain score, Oxford knee score, and Knee Injury and Osteoarthritis Outcome Score), were evaluated preoperatively and at 1 month and 2 years postoperatively.

Results. At the 2-year follow-up interval, no difference was observed in the mean Kujala score (82 ± 2.9 and 83 ± 2.6 for cauterized and non-cauterized knees, respectively; mean difference 0.3; 95% confidence interval, -0.599 to 1.202; $p = 0.509$). The mean VAS pain score was 3 ± 0.9 in the cauterized knee and 3 ± 0.7 in the non-cauterized knee ($p = 0.920$). The mean ROM was $123^\circ \pm 10.8^\circ$ in the cauterized knee and $123^\circ \pm 10.2^\circ$ in the non-cauterized knee ($p = 0.783$). There was no difference between cauterized and non-cauterized patellae in the mean Knee Injury and Osteoarthritis Outcome Score for symptoms (86 ± 4.5 versus 86 ± 3.9 ; $p = 0.884$), pain (86 ± 3.8 versus 86 ± 3.6 ; $p = 0.905$), activities (83 ± 3.2 versus 83 ± 2.8 ; $p = 0.967$), sports (42 ± 11.3 versus 43 ± 11.4 ; $p = 0.942$), and quality of life (83 ± 4.9 versus 83 ± 4.7 ; $p = 0.916$), as well as in the Oxford knee score (40 ± 2.1 versus 41 ± 1.9 ; $p = 0.771$). Complications were uncommon and there were no differences between the groups (one deep venous thromboembolism in

the cauterized group and two in the control group; odds ratio 0.49, 95% CI, 0.04-5.56; $p = 0.57$).

Conclusions. Patellar cauterization results in no difference in anterior knee pain, functional outcomes, and complication rates compared with non-cauterization of the patella in patients who undergo non-resurfaced, simultaneous, bilateral, primary TKA with a minimum of 2 years of follow-up. We do not recommend circumferential patellar cauterization in non-resurfaced patellae in patients who undergo TKA.

INTRODUCTION

Anterior knee pain is a common patient complaint not only before TKA, but also after TKA. It was found in 4% to 49% of patients after TKA, resulting in dissatisfaction, morbidity, and potential revision surgery.^{3,4,6,7,11,16,26,27,34,47} Several studies have investigated the possible sources of anterior knee pain after TKA, including patellofemoral degenerative changes, patellar maltracking, overstuffing, prosthesis design, and preoperative gait patterns, but a single cause or mechanism has not been determined.^{19,28,30,33,36,40}

The patella is innervated by a network of superficial sensory nerves including the anterior femoral cutaneous nerve, lateral and medial femoral cutaneous nerves, and lateral and medial retinacular nerves.²³ Dye¹³ revealed that the peripatellar soft tissue, which is rich in substance P nerve fibers, was a possible source of anterior knee pain. Theoretically, if these nerve fibers are cauterized with electrocautery, denervation of the anterior knee region and relief of patellofemoral pain might be achieved, and a number of studies have tested this premise.^{19,21,23–27}

Rationale

Although some studies have indicated that patellar denervation may decrease the incidence of anterior knee pain^{2,10,37}, others have found that patellar denervation had no substantial effect during follow-up.^{3,29,38,45} Several meta-analyses have been performed to compare cauterized and non-cauterized patellae. Nevertheless, controversy still exists, which is partly related to provided evidence. One meta-analysis did not provide a quality assessment of analyzed articles¹⁵, while another showed a moderate risk of bias²² and others showed a low risk of bias.^{9,44,46} Zhang et al.⁴⁶ showed there was a decrease in the incidence of anterior knee pain but no difference in patellar scores. Cheng et al.⁹ combined randomized and non-randomized controlled trials in their meta-analysis, which may have caused bias, and also showed no clinical difference between cauterized and non-cauterized patellae. Furthermore, their meta-analysis had heterogeneous implants and surgical techniques (for example, different implants and techniques of cauterization and limited data on the depth of cauterization). This will cause bias in comparing results. Additionally, most studies were performed in unilateral TKA, introducing a difference in pain perception between patients, which is known to be large. Only two studies compared cauterized and non-cauterized unresurfaced patellae in patients undergoing simultaneous, bilateral TKA. One of these two studies did not evaluate scoring of anterior knee pain and used a mid-vastus approach², and both studies had small samples and short follow-up periods.^{2,45} To the best of our knowledge, no study has evaluated the effect of patellar denervation on the presence of anterior knee pain in unresurfaced patellae undergoing simultaneous, bilateral TKA with mid-term follow-up. We hypothesized that patellar circumferential cauterization will not result in less pain,

a better outcome, or difference in complication rate in patients who undergo TKA with non-resurfaced patellae.

Research Questions

We evaluated patients undergoing bilateral, simultaneous TKA procedures without patellar resurfacing to ask: (1) Does circumferential patellar cauterization decrease anterior knee pain (Kujala score) postoperatively compared with non-cauterization of the patella? (2) Does circumferential patellar cauterization result in better functional outcomes based on patient report (VAS score, Oxford knee score, and Knee Injury and Osteoarthritis Outcome Score) than non-cauterization of the patella? (3) Is there any difference in the complication rate (infection, patellar maltracking, fracture, venous thromboembolism, or reoperation rate) between cauterized patellae and non-cauterized patellae?

PATIENTS AND METHODS

Study Design and Setting

This was a prospective study of 78 consecutive patients who underwent simultaneous, bilateral primary TKA between February 2015 and October 2016 at Medistra Hospital, Jakarta. During simultaneous, bilateral TKA, cauterization of the patella was performed on all right knees. Thus, a quasi-randomized study design was used in which each patient served as his or her own control, with the right leg in each patient receiving circumferential denervation. The research study was approved by our institutional review board. All patients gave informed consent for participation in the study.

Participants

The inclusion criteria were patients with primary, bilateral patellofemoral knee osteoarthritis (minimum Kellgren-Lawrence Grade 3) who underwent simultaneous, bilateral TKA. Patients with rheumatoid arthritis, infected or septic arthritis, other inflammatory arthritis, secondary or traumatic osteoarthritis, preexisting or congenital bony deformities, severe knee deformities (a varus or valgus deformity) greater than 15°, flexion contracture greater than 10°, patellar dislocation, or preexisting comorbidities (such as diabetes mellitus or chronic heart disease) were excluded. Patients were followed for a minimum of 2 years (mean 30 ± 5.9 months; range 24–45 months).

Study Flow

A total of 78 patients (156 knees) were included in this study, based on the inclusion and exclusion criteria. However, 6% (five of 78) were lost to follow-up (Fig. 1). Sixty-seven women and six men with a mean age of 66 years (range 45–83 years) and a mean BMI of 28 kg/m^2 (range 22–38.1 kg/m^2) participated in this study.

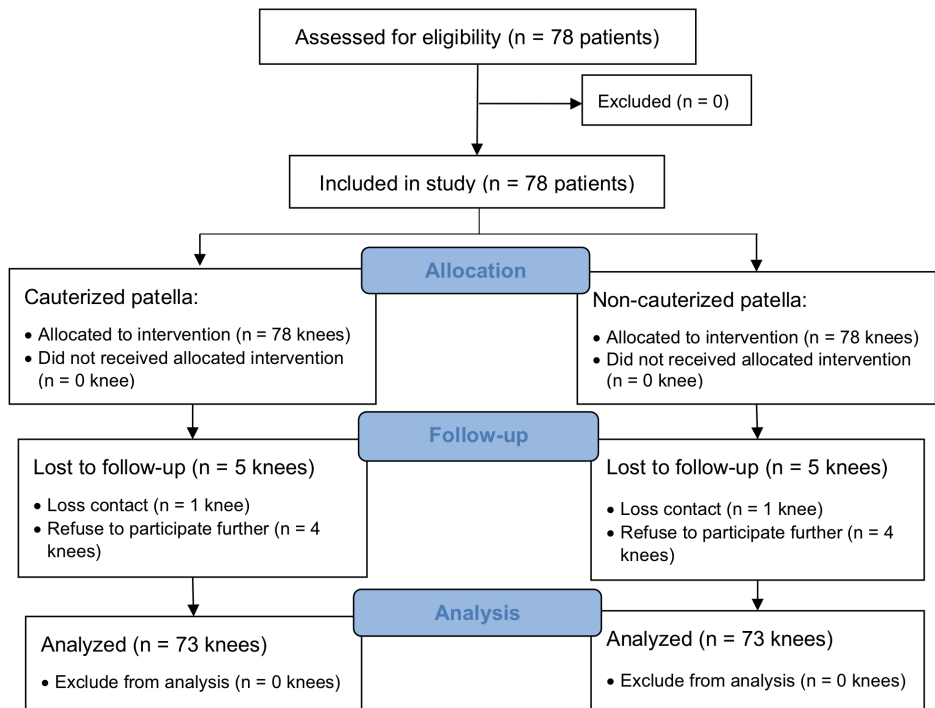


Fig. 1 This figure shows a flowchart of patients selected for inclusion in the study.

Variables, Clinical Outcome Measures, Data Sources, and Bias

Anterior knee pain was evaluated using the Kujala score²⁰, which has been shown to have high internal consistency (0.83-0.91)¹⁸. Functional outcome was evaluated using ROM, VAS score for pain while walking, Knee Injury and Osteoarthritis Outcome Score, and Oxford knee score. Clinical outcomes were evaluated preoperatively and at 1 month and 2 years postoperatively by a single orthopaedic surgeon (KN), who was not a part of the main surgical team. Patients were blinded about which side underwent patellar denervation. The evaluator was not involved in providing the interventions and was blinded to group allocation until the end of the study.

There were no differences in preoperative clinical outcome assessments (ROM, VAS, Knee Injury and Osteoarthritis Outcome Score, Oxford knee score, and Kujala score), femoral anterior condylar ratio, mechanical femorotibial angle, and radiologic severity (determined with the Kellgren-Lawrence grading system) between knees with circumferential electrocauterization of the patellar rim and those without (Table 1). There were no differences in the anterior condylar ratio (0.3 ± 0.1 versus 0.2 ± 0.1 ; $p = 0.192$) or in the mechanical femorotibial angle ($177^\circ \pm 3^\circ$ versus $178^\circ \pm 2^\circ$; $p = 0.751$) between the two groups postoperatively.

Radiographic Assessment

Bilateral knee and long-leg standing radiographs were taken before surgery, and another radiograph was taken 24 hours after surgery. The mechanical femorotibial angle of both knees was measured using the long-leg standing radiograph. True lateral-knee radiographs were used to analyze the femoral anterior condylar ratio using digital image viewer software (General Electric Centricity Digital Imaging and Communications in Medicine Viewer 3.1.4., Chicago, IL, USA). The anterior condylar ratio was used to assess restoration of the patellofemoral joint and evaluate overstuffing of the patellofemoral joint. Overstuffing of the patellofemoral joint occurs when there is an increase in the thickness of the patellofemoral joint. It has been reported to lead to maltracking and wear, stretching of the medial patellofemoral ligament, anterior knee pain, and limited ROM of the knee⁵. Overstuffing might change the patella-to-femur distance, leading to change in the moment arm of the quadriceps, which might be evaluated using the anterior condylar ratio. The femoral anterior condylar ratio is the ratio between the femoral anterior condyle's height and the femoral shaft's diameter, as measured 5 cm above the superior pole of the patella (Fig. 2). An independent radiologist (SI) performed all radiographic evaluations.

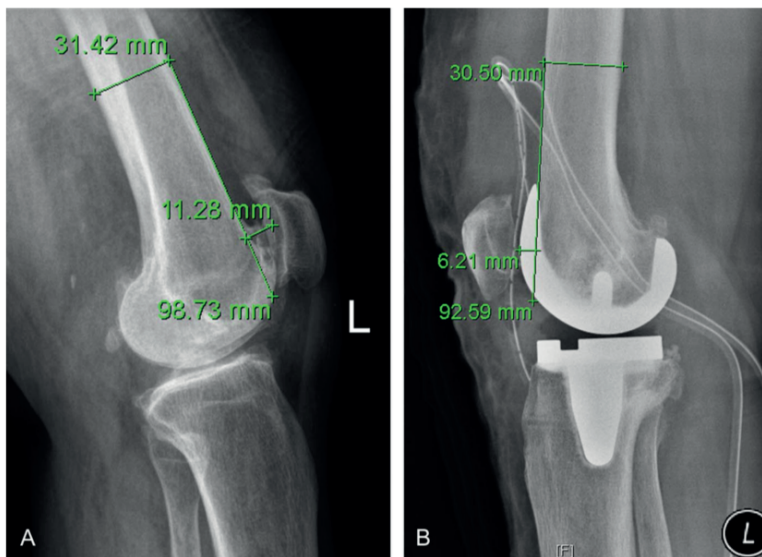


Fig. 2 This figure shows a lateral knee radiograph for measurement of the anterior condylar ratio, which was obtained by dividing the peak anterior condyle's height by the diameter of the femur (A) preoperatively and (B) postoperatively.

Table 1. Patient demographics and clinical outcome scores

Characteristics	Patellar Denervation	Left knee	p value
	mean $\pm$ SD	mean $\pm$ SD	
Age (years)	66 $\pm$ 7	66 $\pm$ 7	
BMI (kg/m ²)	28.3 $\pm$ 4	28.3 $\pm$ 4	
Gender, n (%)			
Women	67 $\pm$ 92	67 $\pm$ 92	
Men	6 $\pm$ 8	6 $\pm$ 8	
Preoperative KOOS for symptoms	45 $\pm$ 12	44 $\pm$ 12	0.787
Preoperative KOOS for pain	46 $\pm$ 12	46 $\pm$ 12	0.918
Preoperative KOOS for activities of daily living	46 $\pm$ 14	45 $\pm$ 14	0.841
Preoperative KOOS for sports and recreation	13 $\pm$ 8	13 $\pm$ 8	0.879
Preoperative KOOS for quality of life	25 $\pm$ 9	25 $\pm$ 9	0.730
Preoperative Oxford knee score	23 $\pm$ 3	24 $\pm$ 3	0.712
Kujala preoperative	40 $\pm$ 9	41 $\pm$ 9	0.707
Preoperative VAS	8 $\pm$ 1	8 $\pm$ 1	0.410
Preoperative ROM (°)	101 $\pm$ 19	100 $\pm$ 20	0.662
Preoperative femorotibial angle (°)	189 $\pm$ 5	191 $\pm$ 6	0.051
Postoperative femorotibial angle (°)	177 $\pm$ 3	178 $\pm$ 2	0.751
Preoperative anterior condylar ratio	0.3 $\pm$ 0.1	0.3 $\pm$ 0.1	0.744
Delta anterior condylar ratio (difference between preoperative and post anterior condylar ratio)	0.05 $\pm$ 0.1	0.06 $\pm$ 0.1	0.548
Postoperative anterior condylar ratio	0.3 $\pm$ 0.1	0.2 $\pm$ 0.1	0.192
Kellgren-Lawrence grade, n (%)			0.606
3	25 $\pm$ 34.2	28 $\pm$ 38.4	
4	48 $\pm$ 65.8	45 $\pm$ 61.6	

KOOS = Knee Injury and Osteoarthritis Outcome Score

Description of Surgical Procedure

A single experienced surgeon (NCB) performed all surgeries. The implanted prosthesis was the ATTUNE cruciate-retaining prosthesis (DePuy Synthes, Warsaw, IN, USA) with a fixed-bearing insert. All patients were intravenously administered 8 mg of dexamethasone 1 hour before surgery to reduce postoperative pain and nausea, as well as 750 mg of tranexamic acid 1 hour before and 6 hours after the procedure to reduce bleeding. A tourniquet was used during the procedure. The operation was always performed first on the right side, regardless of the severity of arthritis, through a standard medial parapatellar approach. A tibial cut was made perpendicular to the mechanical axis using an extramedullary alignment guide with the slope set at 7°. A distal femoral cut was made in 6° of valgus using an intramedullary femoral alignment guide, and the extension gap was measured using spacer blocks. Femoral rotation and the posterior femoral condyle

cut were determined using a hybrid method, a combination of the measured resection technique and gap-balancing technique. The flexion gap was measured using spacer blocks. The posterior femoral osteophytes were excised; subsequently, trial implants were inserted to assess the joint space; varus and valgus stability, patellar tracking, and ROM were measured; and the pull-out lift-off test³² was performed. Osteophytes of the patella were excised, and no patellae in any knee were resurfaced.

Circumferential electrocautery denervation was always performed on the right patellar rim, regardless of the severity of patellar arthritis, but electrocautery was not performed in the left patella (Fig. 3). Electrocautery was performed using a Valleylab electrocautery unit (Valleylab Inc., Boulder, CO, USA) with monopolar coagulation diathermy of 50 W at a depth of 2 mm to 3 mm and approximately 5 mm circumferentially away from the patellar rim. Patellar tracking was assessed using a “no-thumb test” with the tourniquet deflated and the medial capsule left open. If the knee was stable with no tightness in flexion and extension and no patellar maltracking, based on a tibial and femoral trial evaluation, then the tibial and femoral components were implanted. No patellar maltracking or ligament imbalance was found during the intraoperative evaluation. The wound was closed, and a vacuum drain was used. The same technique was used in the contralateral knee, without circumferential patellar cauterization. The patients were blinded to the cauterized and non-cauterized sides.

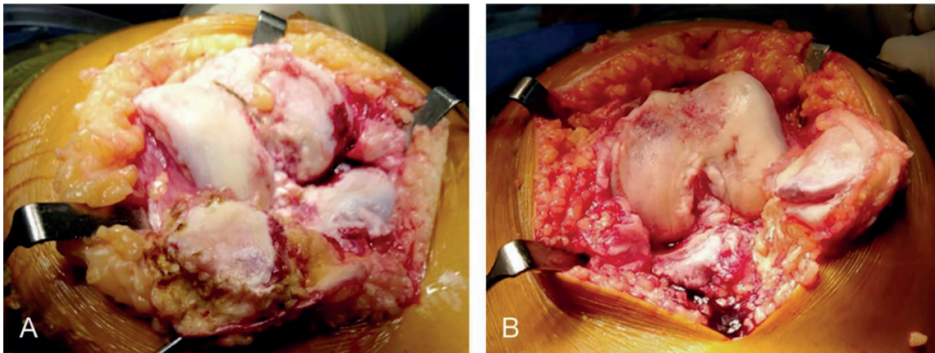


Fig. 3 This figure shows the patella after (A) circumferential cauterization and peripatellar soft-tissue excision and (B) peripatellar soft-tissue excision only in patients undergoing non-resurfaced, simultaneous, bilateral TKA.

Postoperative Care and Rehabilitation

Physiotherapy and exercises were performed as soon as the patient returned to the ward. The vacuum drain was removed at a maximum of 24 hours after surgery. ROM and straight-leg raising exercises were performed continuously during the first day in the ward. A continuous passive motion device was also used while performing ROM exercises twice per day from the first day. An isometric quadriceps strengthening exercise

and assisted weightbearing ambulation using a walker were performed on the second day. Antithrombotic prophylaxis using an oral direct-factor Xa inhibitor (rivaroxaban) was administered to all patients for 14 days postoperatively. The postoperative care and rehabilitation were identical for both knees.

Statistical Analysis

The statistical analysis was performed using IBM Statistical Package for the Social Sciences version 21.0 (SPSS Inc., Chicago, IL, USA). Paired t-tests were used to compare preoperative and postoperative values. Independent t-tests were used to compare the results of knees with circumferential cauterization of the patellar rim and the results of those without. Tests of the correlation between the anterior condylar ratio and VAS score, Kujala score, and Knee Injury and Osteoarthritis Outcome Score for pain were performed to observe any meaningful correlation that could confound the results of the groups. A p value of 0.05 was considered statistically significant. Based on previous studies, the effect size of the Kujala patellofemoral scale ranges from 0.34 to 0.54. Using an α of 0.05, β of 20%, and power of 80%, the total sample size was 115 knees, or 58 knees in each group.

RESULTS

Does Circumferential Patellar Cauterization Decrease Anterior Knee Pain?

There were no differences in the mean Kujala score between the cauterized and non-cauterized groups at 2 years of follow-up (82 ± 2.9 versus 83 ± 2.6 ; mean difference 0.3; 95% confidence interval, -0.6 to 1.2; $p = 0.509$) (Table 2). The mean difference between preoperative and 2-year post-operative scores was 42.1 ± 7.5 (95% CI, -43.9 to -40.3; $p < 0.001$) and 41.7 ± 7.7 (95% CI, -43.5 to -39.9; $p < 0.001$) for the cauterized and non-cauterized groups, respectively. The postoperative Kujala scores of both knees improved at 1 month and 6 months postoperatively but not at 2 years of follow-up (Fig. 4). Moreover, no association was observed between the femoral anterior condylar ratio and anterior knee pain as represented by the VAS score, Kujala score, and Knee Injury and Osteoarthritis Outcome Score (Table 3).

Table 2. Comparison of delta (difference) between baseline (preoperative) and postoperative Kujala scores

Timepoint	Kujala score			
	Patellar denervation	Control	Mean difference between groups (95% CI)	p value (between groups)
1 month	36.5 ± 8.0	36.2 ± 8.3	-0.3 (-0.3 to 2.3)	0.808
2 years	42.1 ± 7.5	41.7 ± 7.7	-0.3 (-2.8 to 2.2)	0.803

There were no baseline differences between the groups. Data are presented as mean difference from the baseline to 1 month and 2 years

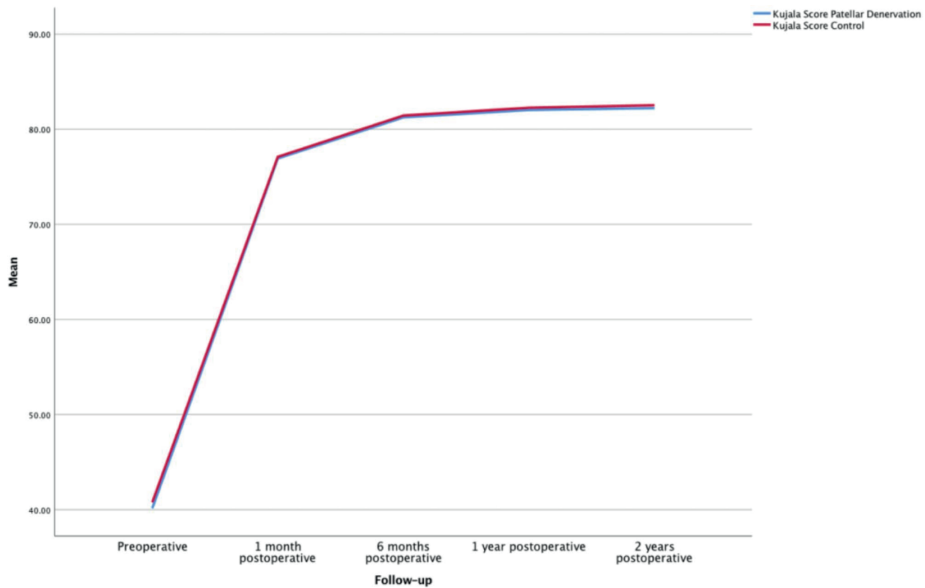


Fig. 4 This figure shows the postoperative Kujala score of both knees over time.

Table 3. Correlation of the delta femoral anterior condylar ratio with Knee Injury and Osteoarthritis Outcome Score, pain score, Kujala score for anterior knee pain, and VAS scores left and right knee

Parameter	Patellar denervation		Control	
	Correlation coefficient	p value	Correlation coefficient	p value
Anterior condylar ratio correlation				
Knee Injury and Osteoarthritis Outcome Score for pain	-0.093	0.432	-0.057	0.630
Kujala score	-0.040	0.737	-0.067	0.576
VAS score	-0.027	0.818	-0.016	0.893

Delta is mean difference from the baseline to 2 years postoperatively

Does Circumferential Patellar Cauterization Result in Better Functional Outcomes Scores?

No differences were found in the mean VAS score between the cauterized and non-cauterized knees (3 ± 0.9 versus 3 ± 0.7 ; $p = 0.920$) (Table 4). The mean difference in the preoperative and 2-year postoperative scores was 5.1 ± 0.8 (95% CI, 4.9-5.3; $p < 0.001$) for the cauterized group and 5.0 ± 1.0 (95% CI, 4.8-5.3; $p < 0.001$) for the non-cauterized group (Table 4). The postoperative VAS score of both knees decreased at 1 month and 6 months postoperatively but not at 2 years of follow-up (Fig. 5). There were no differences in ROM between cauterized and non-cauterized knees postoperatively ($123^\circ \pm 10.8^\circ$ versus $123^\circ \pm 10.2^\circ$; mean difference -0.4 ; 95% CI, -3.9 to 2.9 ; $p = 0.783$) at 2 years of follow-up (Table 4). The mean difference in ROM preoperatively and 2 years postoperatively

was $21.8^{\circ} \pm 16.2^{\circ}$ (95% CI, -25.6 to -18.0; $p < 0.001$) in the cauterized group and $23.2^{\circ} \pm 16.9^{\circ}$ (95% CI, -27.1 to -19.3; $p < 0.001$) in the non-cauterized group. There was also no difference in the Oxford knee score (40 ± 2.1 and 41 ± 1.9 ; $p = 0.771$) between cauterized and non-cauterized patellae, respectively, at 2 years postoperatively (Table 4). The mean difference in the Oxford knee score between preoperatively and 2 years postoperatively was 17.0 ± 2.9 (95% CI, -17.7 to -16.3; $p < 0.001$) and 16.9 ± 3.0 (95% CI, -17.7 to -16.3; $p < 0.001$) in the cauterized and non-cauterized groups, respectively.

There were no differences in all parameters of the Knee Injury and Osteoarthritis Outcome Score between the two groups ($p > 0.05$) (Table 2). There were no differences in the mean Knee Injury and Osteoarthritis Outcome Scores for symptoms (86 ± 4.5 versus 86 ± 3.9 ; mean difference -0.101; 95% CI, -1.478 to 1.275; $p = 0.884$), pain (86 ± 3.8 versus 86 ± 3.6 ; mean difference -0.074; 95% CI, -1.291 to 1.144; $p = 0.905$), activities of daily living (83 ± 3.2 versus 83 ± 2.8 ; mean difference 0.021; 95% CI, -0.965 to 1.006; $p = 0.967$), sports and recreation (42 ± 11.3 versus 43 ± 11.4 ; mean difference 0.137; 95% CI, -3.577 to 3.851; $p = 0.942$), and quality of life (83 ± 4.9 versus 83 ± 4.7 ; mean difference -0.085; 95% CI, -1.673 to 1.503; $p = 0.916$) for cauterized and non-cauterized patellae. Postoperative ROM, Oxford knee scores, and Knee Injury and Osteoarthritis Outcome Score improved in both knees at 1 month postoperatively but not at 2 years of follow-up (Table 4) (Fig. 6).

Is There Any Difference in the Complication Rate of Cauterized Patella?

No complications were associated with infections; patellar fracture, dislocation, subluxation, or maltracking; or extensor mechanism disruption. No revision or reoperation was required for any reason in either group. However, late deep venous thromboembolism was observed in two patients (one knee in the cauterized group and two in the control group) (odds ratio 0.49; 95% CI, 0.04-5.56; $p = 0.57$). These were observed at 6 months postoperatively and were treated successfully. No difference in the complication rate was found between the cauterized and non-cauterized groups.

Table 4. Comparison of delta (difference) between baseline (preoperative) to postoperative clinical outcomes

Score	1 month after surgery				2 years after surgery			
	Patellar denervation	Control	Mean difference (95% CI)	p value	Patellar denervation	Control	Mean difference (95% CI)	p value
VAS activity	3.7 ± 0.9	3.6 ± 0.9	-0.1 (-0.4 to 0.2)	0.417	5.1 ± 0.8	5.0 ± 1.0	-0.08 (-0.4 to 0.2)	0.594
KOOS symptoms	37.1 ± 11.5	37.8 ± 10.9	0.7 (-2.9 to 4.4)	0.699	40.6 ± 10.8	41.4 ± 11.2	0.7 (-2.8 to 4.4)	0.675
KOOS pain	36.8 ± 10.6	36.8 ± 10.1	-0.03 (-3.4 to 3.4)	0.988	40.1 ± 10.7	39.9 ± 10.2	-5.9 (-18.1 to 6.1)	0.332
KOOS ADL	33.1 ± 13.2	34.2 ± 13.4	1.02 (-3.3 to 5.4)	0.645	36.4 ± 13.8	37.3 ± 13.7	0.8 (-3.6 to 5.4)	0.7
KOOS sports and recreation	25.8 ± 11.0	25.5 ± 10.9	-0.4 (-4.0 to 3.2)	0.822	29.2 ± 11.1	30.0 ± 11.4	0.8 (-2.8 to 4.5)	0.661
KOOS QoL	55.6 ± 9.5	55.2 ± 9.5	-0.4 (-3.5 to 2.7)	0.789	57.7 ± 9.6	57.6 ± 9.9	-0.07 (-3.3 to 3.1)	0.963
OKS	15.8 ± 3.1	15.5 ± 3.0	-0.3 (-1.3 to 0.7)	0.522	17.0 ± 2.9	16.9 ± 3.0	0.07 (-1.04 to 0.9)	0.889
ROM (°)	14.8 ± 17.7	15 ± 18.7	0.1 (-5.8 to 6.09)	0.964	21.8 ± 16.2	23.2 ± 16.9	1.4 (-4.1 to 6.8)	0.619

No baseline differences between the groups. Data are presented as mean difference from the baseline to 1 month and 2 years.

KOOS = Knee Injury and Osteoarthritis Outcome Score; ADL = activities of daily living; QoL = quality of life; OKS = Oxford Knee Score

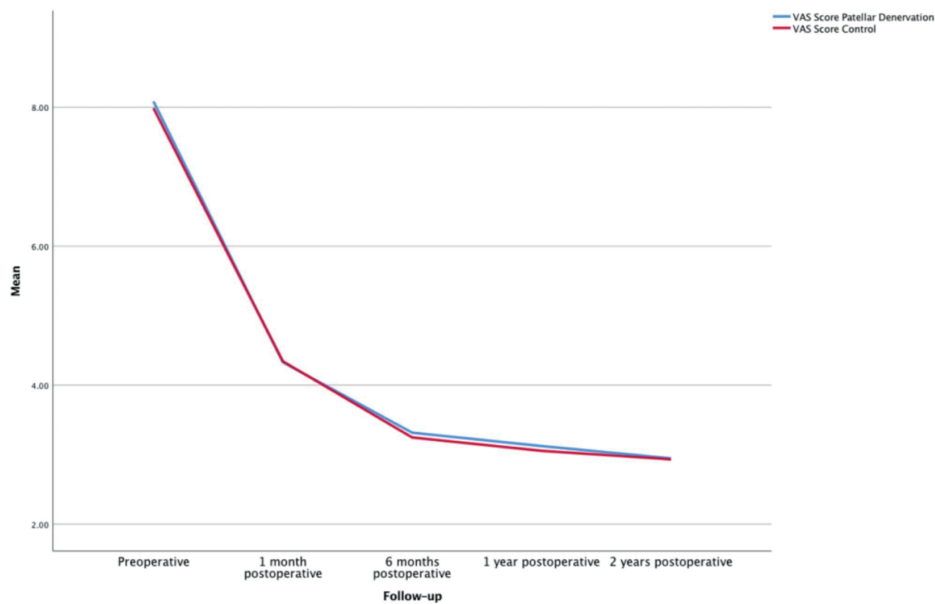


Fig. 5 This figure shows the postoperative VAS pain score of both knees over time.

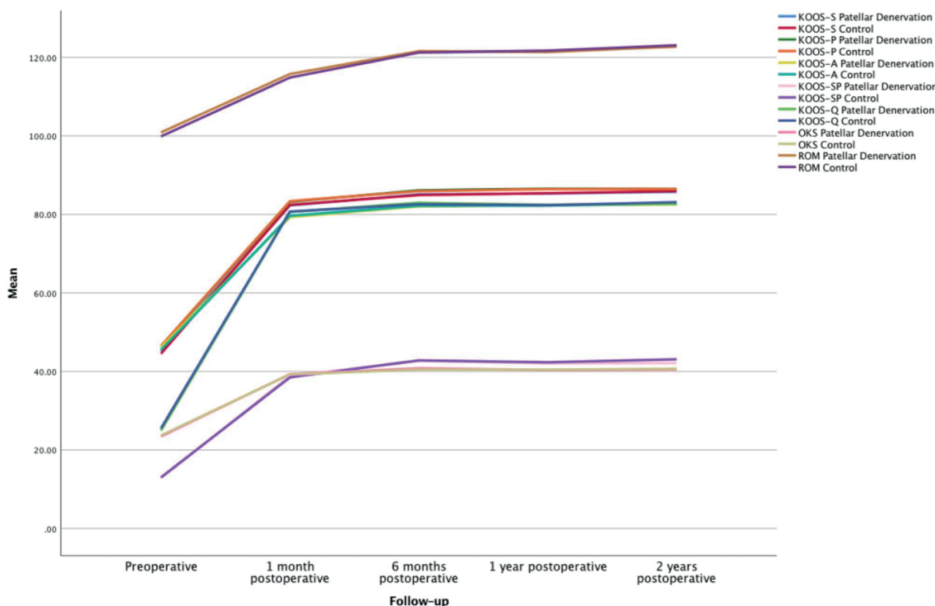


Fig. 6 This figure shows the postoperative clinical outcome assessment of both knees over time.

DISCUSSION

Persistent anterior knee pain after TKA is likely caused by multiple factors that are not always easily identifiable; hence, its management remains difficult.¹¹ Patellar resurfacing, leaving the patella unresurfaced, and patellar circumferential denervation (or not) are advocated as management options for anterior knee pain in patients who undergo TKA.^{12,31} Patellar resurfacing is not routinely performed in Southeast Asian patients. This is because Asian people have a smaller stature and thinner patellae than other individuals do, and the resurfacing procedure tends to cause patellar fracture and associated complications. Second, patellar resurfacing results in additional costs to the patient because of limited national or private healthcare insurance.^{1,8} In this study, we sought to answer the question of whether circumferential patellar denervation in unresurfaced patellae would result in decreased anterior knee pain, improved function, and different complication rates in Southeast Asian patients who undergo simultaneous, bilateral TKA and found it offered no benefit.

Limitations

Our study has several limitations: First, our study was quasi-randomized rather than formally randomized; that is, all patients had the intervention (patellar denervation) in the right knee, while the left knee served as a control. Between-limb differences such as right-sided limb dominance, which is more common³⁹, could have favored the treatment group. Despite this, there were no between-group differences. A possible explanation is that these patients were all Asian, and in Asia, a floor-based lifestyle is culturally normative. Because these people squat, kneel, and hyperflex with both knees, it is possible that limb dominance is not as strong a factor in this population as it is in other populations (such as people from the United States and Europe). To minimize evaluation bias, we blinded patients as to which knee was cauterized, and we assigned a different assessor who was blinded to group allocation and not involved in the intervention or surgical team to evaluate the results. Because the patient was unaware which side underwent patellar denervation, the patient-reported outcome scores were not biased. We reasoned that because the patient's perception of pain was the dominant outcome, the major advantage of this study is that we included only bilateral knees, compared with studies including unilateral knees in a randomized design. Second, a small sample size increases the risk that we will falsely accept the null hypothesis that anterior knee pain between treatment groups was not different (Type II error). The minimal clinically important difference for the Kujala score is 3, which is higher than our delta mean values. Circumferential cauterization did not improve anterior knee pain clinically. Third, we used a cauterization depth of 2 mm to 3 mm. No meta-analysis or even comparative study has compared the cauterization depth. However, one study¹⁴ showed the effectiveness of performing cauterization at a depth of 1 mm to 3 mm in reducing anterior knee pain

in patients undergoing TKA. Fourth, a single independent radiologist interpreted the radiograph results, with no intraobserver reliability. This also might cause bias (intrinsic errors) in radiograph interpretation regarding the femorotibial angle, anterior condyle ratio, and radiographic osteoarthritis. However, because radiologic measurements were performed using digital software with precise landmarks, the possibility of intrinsic errors could be minimized. Generally, bilateral TKAs are performed less often than unilateral TKAs are, and studies comparing the outcome of circumferential cauterization of the patella in patients undergoing simultaneous, bilateral, non-resurfaced TKA are limited. Comparing clinical outcomes with those of the contralateral knees in the same individual undergoing simultaneous, bilateral TKA may eliminate confounders such as differences in pain and subjective perceptions between individuals.

Does Circumferential Patellar Cauterization Decrease Anterior Knee Pain?

Our study found no difference in anterior knee pain between circumferential patellar cauterization and non-cauterization of non-resurfaced patellae in our population at 1 month, 6 months, 1 year, or 2 years after surgery. Similarly, two studies on electrocauterization of the patella compared with non-cauterization had similar results in terms of relief of anterior knee pain after TKA.^{3,29} A prospective randomized controlled trial²¹ compared electrocautery with non-electrocautery and found no substantial differences in pain at 3 months, 6 months, or 5 years of follow-up in patients undergoing non-resurfaced TKA, and similar results were also observed in several other studies.^{2,3,29,45} However, different outcomes were shown by van Jonbergen et al.³⁷; there were improvements in postoperative WOMAC total and function scores in the cautery group compared with the scores of patients in the non-cautery group, but improvements in postoperative WOMAC pain scores were not seen at 1 year of follow-up. However, these differences were not observed at the 3.7-year follow-up interval.³⁸ The differences in early functional outcome in that study, compared with our result, may be because of differing implant designs. We used a fixed-bearing cruciate-retaining implant, while van Jonbergen et al. used a fixed-bearing, posterior-stabilized implant. At least one study has shown that fixed-bearing, cruciate-retaining designs have better clinical outcomes and lower revision rates than fixed-bearing, posterior-stabilized designs.⁴³ The differences in the depth of cauterization (1 mm versus 2 mm to 3 mm) may also play a role in the early result. A meta-analysis¹⁴ has revealed that circumferential patellar cauterization could result in improved knee function scores but did not decrease anterior knee pain. However, even this study showed there was functional improvement; there was no improvement clinically based on the minimal clinically important difference. Two additional meta-analyses^{44,46} revealed that patellar cauterization did not decrease anterior knee pain or improve clinical outcomes at 12 months of follow-up. Despite this, Xie et al.⁴⁴ recommended circumferential cauterization because of its good safety profile. However, Li et

al.²² and Zhang et al.⁴⁶ showed there was improvement, but did not clearly recommend cauterization (Table 5). Other meta-analyses^{9,15} showed no improvement and did not recommend patellar cauterization in patients undergoing TKA. However, these meta-analyses had relatively short follow-up intervals and used different patellar cauterization depths, types of implants, and operative techniques, and some of these studies compared cauterization with non-cauterization in resurfaced patellae.

Does Circumferential Patellar Cauterization Result in Better Functional Outcomes Scores?

In our study, there was no difference in functional outcome scores at 1 month, 6 months, 1 year, or 2 years after surgery between circumferential patellar cauterization and non-cauterization of non-resurfaced patella in patients undergoing simultaneous, bilateral TKA. A study comparing patelloplasty only and patelloplasty combined with circumferential cautery found no major differences in pain and functional outcomes 3 years after surgery.¹⁷ Spencer et al.³⁵ compared resurfaced patellae without denervation with unresurfaced patellae with denervation and found no substantial differences in pain and functional scores after 2 years of follow-up. Consistent with these studies, the reason for our findings are as follows: first, we used “patella-friendly” components in this study. The patella-friendly implant has an extended anterior flange with a deeper and wider trochlear groove. TKA implants with a patella-friendly design might lower the reoperation rate because of patellofemoral problems and postoperative anterior knee pain.^{25,42} Second, there is no consensus regarding the standard circumferential patellar cauterization technique. In our study, patellar cauterization was performed at 2 mm to 3 mm deep and approximately 5 mm circumferentially away from the patellar rim, without damaging the cartilage. Fan et al.¹⁴ recommended patellar electrocauterization of the synovial soft-tissue layer within 1 cm of the circumference of the patella and at a depth of not greater than 1 mm to 3 mm, with 50 W of monopolar diathermy. Third, we excised the peripatellar soft tissues such as the synovium and infrapatellar fat pad in both groups. Peripatellar soft tissue, according to some studies, contains pain-sensitive nerve-end fibers responsible for postoperative anterior knee pain.^{14,23,27,36,37,41,44} Finally, many other factors contribute to anterior knee pain, and some patients experience anterior knee pain after TKA regardless of their preoperative condition.^{1,8,27}

Is There Any Difference in the Complication Rate of Cauterized Patella?

Similar to other previous studies, our study did not reveal a difference in complications between the two groups.^{17,21,36,45,46} Specifically, no complications were associated with patellar fracture, dislocation, subluxation, and maltracking, or an extensor mechanism injury. Revision surgery for pain or a patellofemoral problem was not required. Although not seen in our study, several complications after non-resurfaced patellar cau-

Table 5. Meta-analysis study comparing patellar denervation and non-patellar denervation

Study	Sample size		Outcome	Mean Difference	95% CI	Interpretation
	PD	NPD				
Zhang et al [46]	235	231	Incidence of AKP	0.65 ^a	0.42 to 1.00	No difference
	98	98	VAS	-0.31	-0.81 to 0.19	No difference ($I^2 = 62\%$)
	98	98	Patellar score	1.00	-0.10 to 2.10	No difference ($I^2 = 58\%$)
	154	157	OKS	-0.21	-2.53 to 2.11	No difference ($I^2 = 57\%$)
	98	98	ROM	4.27	1.95 to 6.60	Better in denervation group
	98	98	KSS knee score	2.50	0.34 to 4.67	Better in denervation group
	98	98	KSS function score	4.07	1.34 to 6.80	Better in denervation group
	258	261	Incidence of complication	0.31 ^a	0.05 to 2.06	No difference
	361	360	Incidence of revision	0.56 ^a	0.20 to 1.59	No difference
Cheng et al [9]	222	225	Incidence of AKP	0.71 ^b	0.47 to 1.06	No difference
	148	144	Patellar score	1.14	0.38 to 1.89	Better in denervation group
	166	166	KSS knee score	2.51	0.71 to 4.30	Better in denervation group
Xie et al [44]	166	166	KSS function score	3.12	1.01 to 5.22	Better in denervation group
	327	327	Incidence of Complication	1.05 ^b	0.15 to 7.40	No difference ($I^2 = 53\%$)
	304	307	Incidence of AKP (<12 months)	0.63 ^a	0.44 to 0.88	Higher incidence in non- denervation group
	154	155	VAS (<12 months)	-0.83	-1.10 to -0.56	No difference
	154	157	Patellar score (<12 months)	1.60	0.87 to 2.33	Better in denervation group
	194	194	KSS knee score (<12 months)	2.18	0.16 to 4.21	Better in denervation group
	194	194	KSS function score (<12 months)	2.16	0.26 to 4.06	Better in denervation group
	63	63	ROM (<12 months)	3.50	0.90 to 6.10	Better in denervation group
	229	225	Incidence of AKP (>12 months)	0.69 ^a	0.46 to 1.04	No difference
	189	190	VAS (>12 months)	-0.16	-0.34 to 0.02	No difference
	148	147	Patellar score (>12 months)	-0.41	-1.19 to 0.38	No difference

	201	196	KSS knee score (>12 months)	1.06	-0.65 to 2.76	No difference
	201	196	KSS function score (>12 months)	1.73	-0.08 to 3.55	No difference
	146	143	ROM (>12 months)	1.94	-0.09 to 3.98	No difference
Li et al [25]	201	201	Incidence of AKP	0.67 ^a	0.46 to 0.99	Higher in non- denervation group
	126	129	VAS	-0.63	-0.97 to -0.29	Better in denervation group
	85	85	Patellar score	1.15	0.74 to 1.55	Better in denervation group
	216	216	KSS function score	1.88	0.41 to 3.34	Better in denervation group
	181	181	WOMAC	3.79	1.88 to 5.69	Better in denervation group
	151	151	Infection	1.00 ^a	0.20 to 5.11	No difference
	151	151	Complication related to patella	1.41 ^b	0.27 to 7.27	No difference
Findlay et al [15]	166	166	KSS	0.25	-3.51 to 13.67	No difference
Fan et al [14]	146	143	Patellar score	0.63	0.13 to 1.13	Better in denervation group
	352	352	Incidence of AKP	0.78	0.55 to 1.12	No difference ($I^2 = 70\%$)
	152	152	OKS	1.78	0.24 to 3.32	Better in denervation group
	181	181	WOMAC	3.76	1.71 to 5.81	Better in denervation group
	279	278	KSS knee score	2.09	0.69 to 3.50	Better in denervation group
	279	278	KSS function score	1.93	-1.57 to 5.43	No difference ($I^2 = 80\%$)
	146	143	ROM	3.50	1.82 to 5.18	Better in denervation group

^a means odds ratio (OR);^b means relative risk (RR); patellar denervation/cauterization (PD); non-patellar denervation (NPD); anterior knee pain (AKP); range of motion (ROM); visual analogue scale (VAS); femorotibial angle (FTA); Oxford knee score (OKS); Western Ontario and McMaster Universities osteoarthritis index (WOMAC); Knee Society Score (KSS); activity of daily living (ADL) score; University of California and Los Angeles (UCLA) score.

terization have been described: chondrolysis because of progression of osteoarthritis or mechanical factors²⁷; proprioceptive disturbance after electrocauterization, causing patellar degeneration owing to gait or altered joint loading that could not be detected because of diminished proprioception¹⁷; thermal injury to the patellar tendon, which is an entry point of the patellar vessel that supplies the patella and could lead to osteonecrosis and damage to the extensor mechanism; and direct cartilage damage.^{24,36}

CONCLUSIONS

We found no difference in anterior knee pain, functional outcomes, and complication rates up to 2 years postoperatively between circumferential cauterization and non-cauterization of the patella in patients who underwent non-resurfaced, simultaneous, bilateral TKA. We therefore do not recommend circumferential patellar cauterization in patients undergoing non-resurfaced TKA.

Acknowledgments

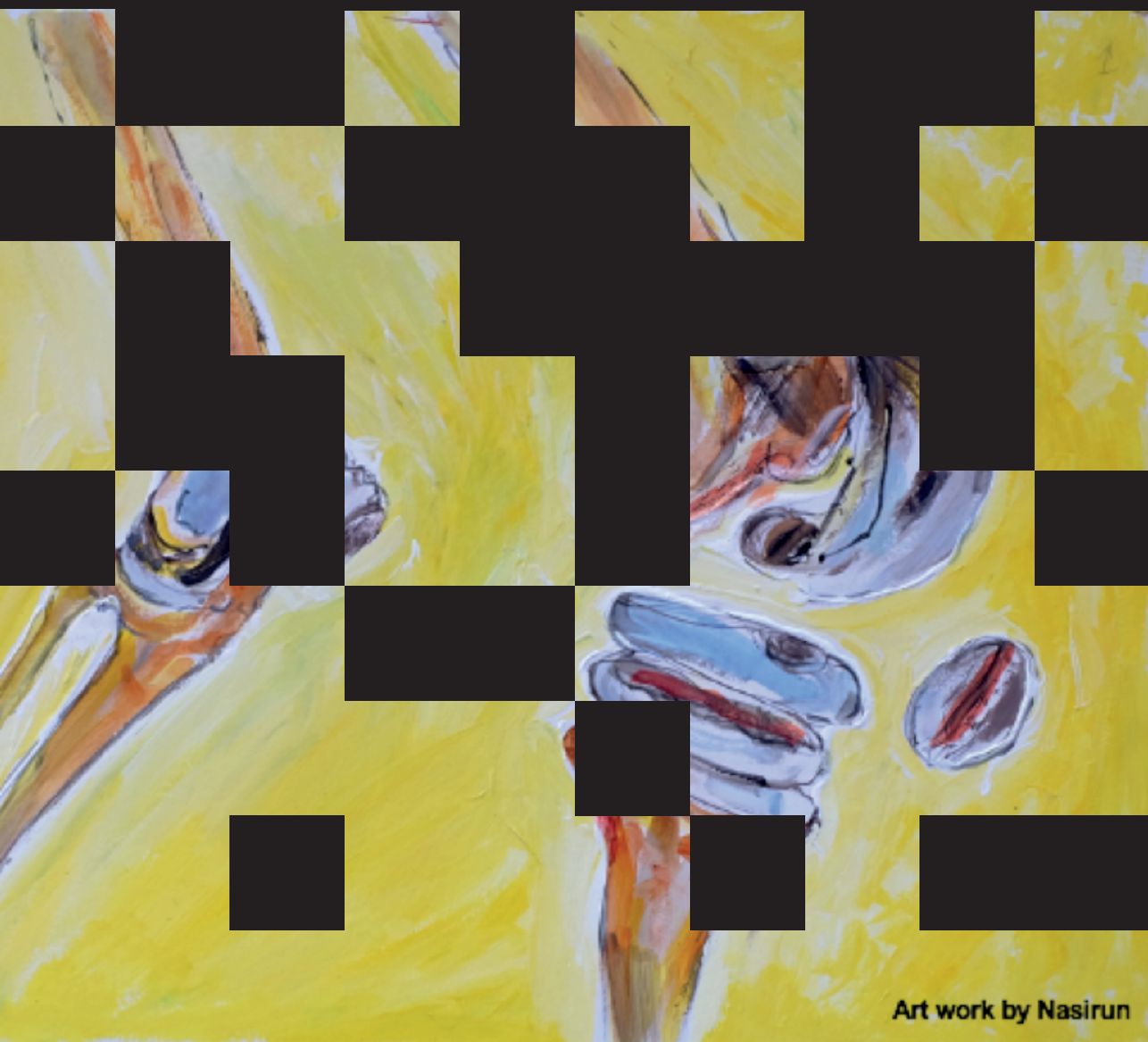
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Art work by Nasirun

Chapter

5

Does accelerometer-based-navigation have any benefit compared to conventional TKA?

A systematic review

Budhiparama N.C.
Lumban-Gaol I.
Ifra N.N.
Parratte S.
Nelissen R.G

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ABSTRACT

Background. Accelerometer-based navigation is a handheld navigation tool that was introduced to offer a simpler technique compared with more-cumbersome computer-assisted surgery (CAS). Considering the increasing number of adopters, it seems important to evaluate the potential clinical benefits of this technology compared with conventional TKA.

Questions/purposes. In this systematic review, we asked: (1) Is accelerometer-based navigation more accurate than conventional TKA? (2) Does accelerometer-based navigation provide better functional outcome than conventional TKA? (3) Does accelerometer-based navigation increase surgical time or decrease the risk of complications or reoperations compared with conventional TKA?

Methods. This systematic review included all comparative prospective and retrospective studies published in the MEDLINE/PubMed and Cochrane libraries over the last 10 years. Inclusion criteria were all studies in English that compared accelerometer-based navigation with conventional TKA. Eleven studies met these criteria with 621 knees in accelerometer-based navigation group and 677 knees in conventional TKA group. Results related to alignment, objective and subjective functional scores, duration of surgery, complications and reoperations were extracted and compared between accelerometer-based-navigation and conventional TKA. Methodological quality was assessed using Methodological Index for Nonrandomized Studies (MINORS) tool (for nonrandomized control trials) and Cochrane Risk of Bias (for randomized control trials (RCTs)). All studies with fair or better quality were included. Four RCTs and six nonrandomized studies comparing accelerometer-based navigation to conventional TKA were found.

Results. Inconsistent evidence on mechanical axis alignment was found, with five of nine studies slightly favoring the accelerometer-based navigation group, and the other four showing no differences between the groups. Only two of eight studies favored accelerometer-based navigation in terms of tibial component alignment in the coronal plane; the other six found no between-group differences. Similarly, mixed results were found regarding other metrics related to component alignment; a minority of studies favored accelerometer-based navigation by a small margin, and most studies found no between-group differences. Only three studies evaluated functional outcome and none of them showed a difference in range of motion or patient-reported outcomes. Most studies, six of seven, found no between-group differences concerning surgical time; one study demonstrated a slight increase in time with accelerometer-based navigation. There were no between-group differences in terms of the risk of complications, which generally were uncommon in both groups, and no reoperations or revisions were reported in either group.

Conclusions. We found conflicting evidence about whether accelerometer-based navigation reduces the number of coronal-plane outliers or improves alignment to a

clinically important degree, and we found no evidence that it improves patient-reported outcomes or reduces the risk of complications or reoperations. Accelerometer-based navigation may increase surgical time. The overall quality of the evidence was low, which suggested that any observed benefits were overestimated. Given the absence of higher-quality evidence demonstrating compelling benefits of this accelerometer-based navigation technology, it should not be widely adopted.

INTRODUCTION

Total knee arthroplasty is an effective procedure to treat knee osteoarthritis^{7,21,39}, and in so doing, to restore knee alignment and ligament balance.^{7,16,18,21,23} Proper component alignment is important to improve the likelihood of functional restoration, patient satisfaction, and TKA survivorship.^{7,16} Data from national implant registries with more than 95% completeness (National Joint Registry, Sweden, Australia, Netherlands) showed that wear and loosening—the risks of which are influenced by component alignment—account for 22% to 30% of revisions, comparable to the risks of instability and infection.^{33,60} Despite emerging new concepts concerning the ideal alignment in TKA, standard mechanical alignment remains the most widely used approach.^{8,22,36,51–53,64} However, using conventional mechanical alignment guides in TKA might lead to component alignment error exceeding 3° on the tibia.³⁸ In one previous study, the recommended alignment in the coronal plane (within 3° of a neutral mechanical axis) was achieved in only 70% to 80% of patients undergoing conventional TKA using extra and intramedullary guides.⁴¹ Computer-assisted surgery systems were developed to improve the accuracy of component positioning; there is some evidence that navigation reduces the risk of revision and implant loosening and early migration^{11,61}, but other studies found no improvement in patient-reported outcomes or ROM^{18,30,35,40,47} with no difference in the risk of tibial component migration compared with conventional TKA.⁵⁰ Accelerometer-based navigation is a portable surgical navigation system that does not use a large computer console for TKA. After early validation studies, Nam et al⁴⁴ first studied accelerometer-based navigation in 2011 in a cadaveric study. Accelerometer-based navigation is a handheld, single-use, sterile device used within the operative field to determine the hip center of rotation and the femoral mechanical axis, which are used to determine the resection planes of the distal femur and the proximal tibia.²⁷ These systems are wireless and imageless, and they capture data during the procedure, and display those data directly on pods, which are attached to the femoral and tibial resection guides within the surgical field. The systems guide resection angles in the coronal and sagittal planes, and confirm alignment accuracy of the femoral and tibial components after resection.⁵⁴ As appealing as this sounds, studies have disagreed about the advantages and disadvantages of these systems in TKA, in terms of TKA alignment, surgical time, and a variety of clinical and functional outcomes.^{17,18,27,32,45}

In light of these controversies, we sought to perform a systematic review of accelerometer-based navigation in TKA, and we asked the following questions: (1) Is accelerometer-based navigation more accurate than conventional TKA? (2) Does accelerometer-based navigation provide better functional outcome than conventional TKA? (3) Does accelerometer-based navigation increase surgical time or decrease the risk of complications or reoperations compared with conventional TKA?

MATERIALS AND METHODS

We performed a systematic review using the MEDLINE/PubMed and Cochrane Library databases to identify relevant studies published between January 2008 and May 2018 that met the eligibility criteria to compare the efficacy of accelerometer-based navigation and conventional TKA.

Medical subject headings (MeSH) and key terms were used with the search criteria: limited to humans and published in English; with keywords: (((Total knee arthroplasty) OR Total Knee Replacement) AND Accelerometer-based navigation) OR Handheld navigation) OR KneeAlign2) OR IASSIST) AND Conventional arthroplasty))) was done. Two authors (NCB, ILG) separately reviewed all abstracts for eligibility. An initial search yielded 39 references; after using the selection criteria 28 studies were excluded due to the following reasons: irrelevant topic (nonTKA), still an ongoing clinical study (abstract only), not a comparative study, and duplicate paper. After exclusions, 11 studies remained after evaluation by the two authors. We hand-searched study bibliographies to ensure there were no other eligible trials; there were none.

Using the Methodological Index for Non-Randomized Studies (MINORS) tool, we reviewed these articles for methodological quality; one paper was excluded because of high risk of bias (MINORS score of 12; Fig. 1) done by Vanniar et al.⁶² We assessed all articles for methodological quality using the MINORS tools for nonrandomized studies (Table 1), which consists of 12 points: 8 points for a noncomparative study and additional 4 points for a comparative study⁵⁴. The points for a noncomparative study are: (1) stated aim of study; (2) inclusion criteria; (3) collection data; (4) endpoint of study; (5) unbiased evaluation; (6) follow-up period; (7) loss of follow-up; (8) prospective calculation of sample size. The additional points for a comparative study are: (1) gold standard for control group; (2) contemporary groups; (3) baseline equivalence; (4) statistical analyses. These items are scored 0 (not reported), 1 (reported but not adequately), or 2 (reported and adequately). A score ≤ 12 is considered to be of low quality (high risk of bias), whereas a study with MINORS score > 12 is thought to be of high quality. We used the Cochrane Risk of Bias tools for randomized control trials (Table 2). The Cochrane Risk of Bias tools¹⁰ consist of 7 points: (1) random sequence generation; (2) allocation concealment; (3) selective reporting; (4) other bias; (5) blinding of participants and personnel; (6) blinding of outcomes assessment; (7) incomplete outcomes data. These items are assessed for high, low, or unclear and each study is interpreted with good, fair, or poor quality based on the criteria.

From these studies, six studies were assessed with MINORS and four studies with Cochrane Risk of Bias tools. In all, 10 studies were included. All studies adequately reported a clear study aim and outcome measures (Table 3). In light of the small number of RCTs and the overall study quality (which was only fair), we did not perform a meta-analysis.

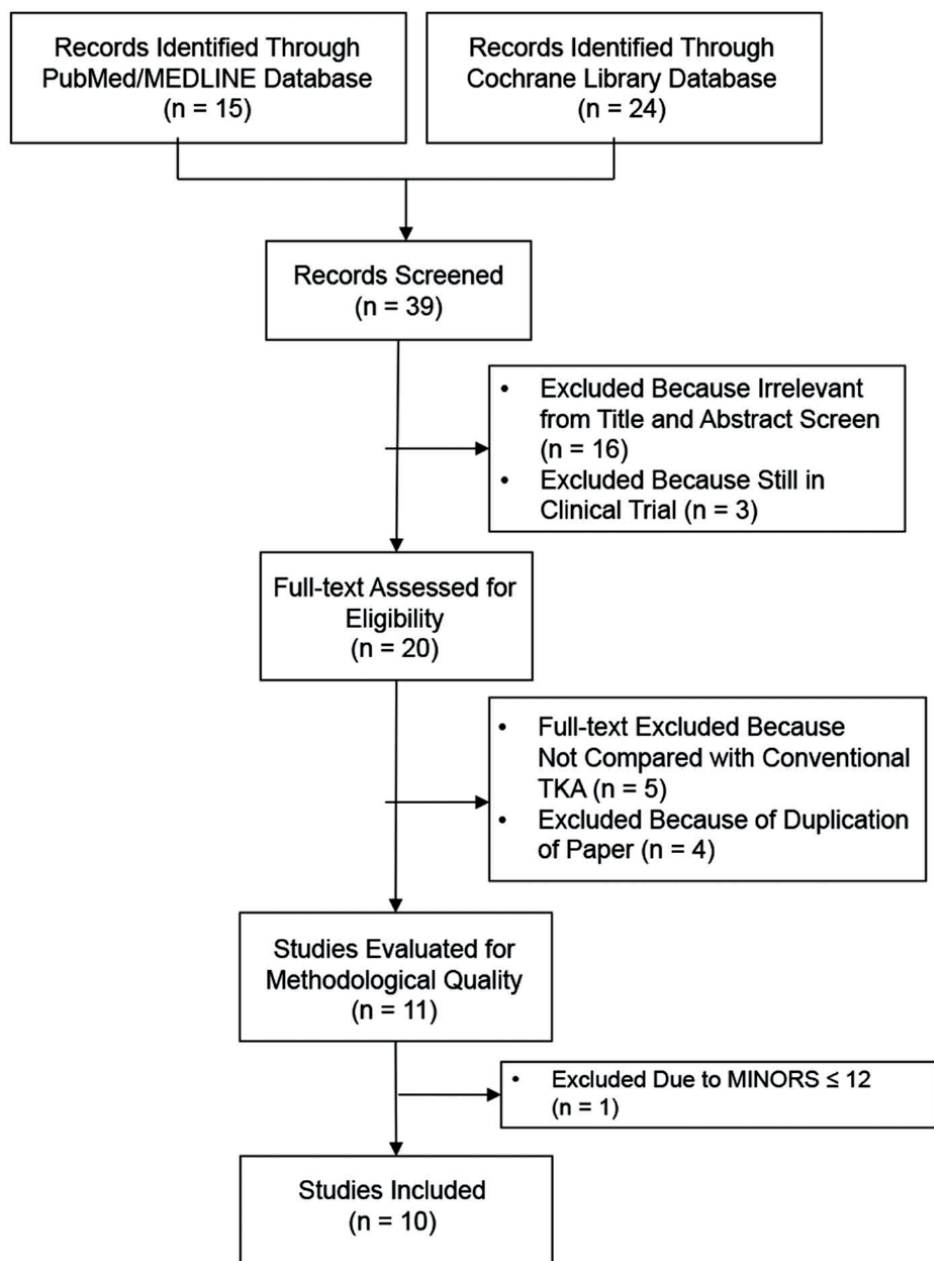


Figure 1. Flow chart shows the numbers of articles initially identified and exclusion and inclusion steps

Table 1. Quality scoring of included studies based on the Methodological Items for Non-Randomized Studies (MINORS) criteria*

Study	MINORS items												MINORS score
	1	2	3	4	5	6	7	8	9	10	11	12	
Liow et al ³⁵	2	1	2	2	0	2	2	2	2	2	2	2	21
Moo et al ⁴¹	2	2	2	2	0	1	2	0	2	2	2	2	19
Goh et al ¹⁷	2	2	2	2	2	2	2	2	2	2	1	2	23
Kawaguchi et al ²⁷	2	2	2	2	2	2	2	2	2	2	1	2	23
Ueyama et al 2017 ⁶⁰	2	0	2	2	0	1	2	2	2	2	1	2	18
Ueyama et al 2018 ⁶¹	2	2	2	2	2	1	2	2	2	2	2	2	23
Vanniar et al 2018⁶²	2	0	0	0	0	0	2	1	1	2	1	1	10

* Eleven included studies, seven of which were retrospective trials analyzed with the MINORS criteria.³¹

MINORS tools consist of 12 points, with 8 points for non-comparative study and additional 4 points for comparative study. Points for non-comparative study are: (1) consist of stated aim of study; (2) inclusion; (3) collection data; (4) endpoint of study; (5) unbiased evaluation; (6) follow up period; (7) loss of follow up; (8) prospective calculation of sample size. Additional for comparative study are: (1) gold standard for control group; (2) contemporary groups; (3) baseline equivalence; (4) statistical analyses. These items are scored 0 (not reported), 1 (reported but not adequately), or 2 (reported and adequately). Score ≤ 12 is considered to be of low quality (high risk of bias), where as a study with MINORS score > 12 is thought to be of high quality. The **bold** is excluded due to high risk of bias (MINORS score ≥ 12)

In each article, we reviewed alignment, including (1) hip-knee-ankle angle (HKA) or mechanical axis (MA); (2) placement of the femoral component through the coronal femoral alignment (CFA), sagittal femoral alignment (SFA), and axial femoral plane (AFP); (3) placement of the tibial component, which involves coronal tibial alignment (CTA), sagittal tibial alignment (STA) and axial tibial plane (ATP); (4) outliers, defined as deviation $> 3^\circ$ of neutral alignment for HKA or MA, deviation $> 3^\circ$ from 90° for CFA, SFA, and CTA, and also $> 3^\circ$ deviation from 87° for STA, patient-reported outcomes, range of motion, operative time, complications, or reoperations between accelerometer-based navigation and conventional TKA. For alignment, we used full limb on standing position. A minimum of 2 weeks postoperative follow-up was required to include data about patient-reported outcomes.

Table 2. Cochrane risk of bias tools for randomized controlled trials (RCT)

Cochrane risk	Nam et al ⁴²	Gharaibeh et al ¹⁶	Ikawa et al ²³	Kinney et al ³⁰
Random sequence generation	Low risk	Low risk	Low risk	Low risk
Allocation concealment	Low risk	Low risk	Low risk	Low risk
Selective reporting	Low risk	Low risk	Low risk	Low risk
Other bias	High risk	Low risk	Unclear risk	Unclear risk
Blinding of participants and personal	Low risk	Unclear risk	Low risk	Low risk
Blinding of outcome assessment	Low risk	Low risk	Low risk	Low risk
Incomplete outcome data	Low risk	Low risk	Low risk	Low risk
Conclusion	Fair quality	Fair quality	Fair quality	Fair quality

Cochrane Risk of Bias tools consist of 7 points¹⁰: (1) random sequence generation; (2) allocation concealment; (3) selective reporting; (4) other bias; (5) blinding of participants and personnel; (6) blinding of outcome assessment; (7) incomplete outcome data. These items are assessed for high, low, or unclear and each study is interpreted with good, fair, or poor quality based on the criteria.

RESULTS

Accuracy

We observed small, inconsistent differences in MA and HKA; five of nine studies favored accelerometer-based navigation^{17,18,24,28,37}, while four of nine found no differences between the study groups.^{31,42,43,58} In terms of coronal-axis alignment of the femoral component, seven of nine studies favored accelerometer-based navigation^{17,18,24,28,37,58,59}, but the effect size generally was small. Only three studies compared the sagittal placement of femoral component and none of those studies showed a difference between accelerometer-based navigation and the conventional TKA group.^{17,58,59} Only one study evaluated the axial placement of the femoral component⁶¹; it found no differences between the study groups (Table 3).

Of the nine studies that evaluated tibial component coronal plane alignment, only two favored accelerometer-based navigation, and the differences were small^{28,37}; the other seven studies found no differences between the groups.^{17,18,31,42,43,58,59} None of the five studies that evaluated sagittal alignment of the tibial component found differences between the study groups.^{17,42,43,58,59} The one study that evaluated axial placement of the tibial component⁵⁹ found no between-group differences.

Only two of six studies that evaluated the proportion of patients with outlier alignments supported accelerometer-based navigation^{28,37}; the other four found no differences in this important endpoint.^{17,18,42,43}

A minority of studies (four of nine) that evaluated CFA outliers favored accelerometer-based navigation^{18,24,58,59}; the remainder did not.^{17,28,31,42,43} Only one study⁵⁸ of five^{17,28,42,58,59} that evaluated SFA outliers supported accelerometer-based navigation over conventional alignment techniques. Regarding axial placement of femoral com-

Table 3. Studies comparing accelerometer-based navigation comparing ABN with conventional TKA

Authors	Year	Journal	Study design	Follow-up		Results		p value	
				Accelerometer	Conventional	Accelerometer	Conventional		
Liow et al ³⁵	2016	Archives of Orthopaedic Trauma and Surgery	Mechanical alignment, placement of component, KSS, OKS, SF-36	92	100	83.9 ± 21.8	72.5 ± 14.6	<0.001	
					1 month for radiological; 6 months for KSS, OKS, and SF-36	Operation time (minutes)			
						MA shifting (°)	1.9 ± 1.4	2.8 ± 2.0	0.001
						CFA shifting (°)	1.6 ± 1.3	2.1 ± 1.5	0.035
						CTA Shifting (°)	1.6 ± 1.2	2.1 ± 1.5	0.024
						Knee Society Knee Score	77.2 ± 16.2	81.2 ± 12.7	0.110
						Knee Society Functional Score	71.7 ± 16.6	69.9 ± 16.4	0.530
						OKS	19.3 ± 4.8	19.5 ± 4.4	0.690
						SF-36 PCS	47.1 ± 9.7	47.1 ± 10.8	0.991
						SF-36 MCS	57.5 ± 9.0	55.5 ± 10.2	0.231
		Complications	0	0					
		MA outliers	8.7	26	0.001				

Table 3. Studies comparing accelerometer-based navigation comparing ABN with conventional TKA (continued)

Authors	Year	Journal	Study design	Follow-up		Results		p value
				Accelerometer	Conventional	Accelerometer	Conventional	
Moo et al ⁴¹	2018	<i>Journal of Orthopaedic Surgery</i>	Mechanical alignment, placement of component, and duration of surgery	30	30	Operation time (minutes)	96.25 ± 6.25	90.62 ± 4.37
						MA (°)	176.75 ± 0.75	176.75 ± 0.75
						CFA (°)	91.75 ± 0.75	92 ± 0.5
						SFA (°)	89.75 ± 0.75	92 ± 1.5
						CTA (°)	91.25 ± 0.75	90 ± 0.5
						STA (°)	84.25 ± 0.75	85 ± 1
						MA outliers (%)	43	36
						CFA outliers (%)	26	30
						SFA outliers (%)	43	53
						CTA outliers (%)	20	13
						STA outliers (%)	23	16

Table 3. Studies comparing accelerometer-based navigation comparing ABN with conventional TKA (continued)

Authors	Year	Journal	Study design	Follow-up		Results		p value	
				Accelerometer	Conventional	Accelerometer	Conventional		
Goh et al ¹⁷	2018	<i>The Journal of Arthroplasty</i>	Mechanical alignment, ROM, KSS, OKS, SF-36 (PCS and MCS), and operation time	38	76	Operation time (minutes)	83.9 ± 21.8	76.6 ± 17.9	0.059
					1 month for radiological; 6 months and 2 years for KSS, OKS, and SF-36	ROM (°)	114.3 ± 12.3	111.0 ± 13.0	0.196
						MA shifting (°)	1.8 ± 1.3	2.8 ± 2.1	0.008
						CFA shifting (°)	1.3 ± 1.1	2.2 ± 1.6	0.002
						CTA shifting (°)	1.6 ± 1.3	2.1 ± 1.6	0.09
						MA outliers (%)	10.5	25	0.07
						CFA outliers (%)	7.9	25	0.029
						CTA outliers (%)	15.8	19.7	0.614
						Knee Society Knee Score	82.4 ± 12.8	84.9 ± 12.5	0.32
						Knee Society Functional Score	71.0 ± 18.5	75.2 ± 16.4	0.219
						OKS	19.4 ± 5.8	17.9 ± 3.4	0.084
		SF-36 PCS	46.2 ± 11.3	49.9 ± 8.3	0.050				
		SF-36 MCS	56.5 ± 9.8	56.5 ± 9.8	1				
		Complication	0	0					

Table 3. Studies comparing accelerometer-based navigation comparing ABN with conventional TKA (continued)

Authors	Year	Journal	Study design	Follow-up		Results		p value
				Accelerometer	Conventional	Accelerometer	Conventional	
Kawaguchi et al ²⁷	2017	<i>Knee Surgery and Related Research</i>	HKA, ROM, placement of component, KSS, and operation time	34	33	123.3 ± 20.8	121.1 ± 18.3	0.647
					1 year			
						Operation time (min)		
						ROM (°)	122.3 ± 9.9	0.616
						HKA (°)	178.9 ± 1.6	< 0.01
						CFA (°)	89.1 ± 1.1	< 0.01
						CTA (°)	89.3 ± 1.6	0.473
						HKA outliers (%)	9.1	0.046
						CFA outliers (%)	0	
						SFA outliers (%)	9	
						Knee Society Knee Score	92.1 ± 6.7	0.698
						Knee Society Functional Score	75.7 ± 12.3	0.406
						Complication	0	0

Table 3. Studies comparing accelerometer-based navigation comparing ABN with conventional TKA (continued)

Authors	Year	Journal	Study design	Follow-up		Results		p value		
				Accelerometer	Conventional	Accelerometer	Conventional			
Ueyama et al ⁶⁰	2017	Orthopedics	Operating time, range of motion, KSS, mechanical alignment, placement of component	67	75	2 weeks postoperative	Operation time (minutes)	115 ± 10	113 ± 13	0.39
							ROM (°)	121.8 ± 9.4	123.7 ± 9.3	0.21
							MA (°)	177.2 ± 1.2	177.5 ± 1.6	0.26
							CFA (°)	89.8 ± 1.1	89.0 ± 1.9	0.013
							CTA (°)	89.8 ± 1.4	90.1 ± 1.4	0.17
							STA (°)	87.2 ± 1.9	86.9 ± 2.1	0.46
							SFA shifting (°)	0.38 ± 2.6	0.46 ± 2.6	0.83
							CFA outliers (%)	1.5	13.3	0.01
							SFA outliers (%)	13.4	21.3	0.27
							CTA outliers (%)	3.0	4.0	1
							STA outliers (%)	3.0	8.0	0.28
							Knee Society Knee Score	76.8 ± 7.8	74.9 ± 7.7	0.20
							Knee Society Functional Score	75.3 ± 5.7	74.1 ± 6.1	0.19

Table 3. Studies comparing accelerometer-based navigation comparing ABN with conventional TKA (continued)

Authors	Year	Journal	Study design	Follow-up		Results		p value
				Accelerometer	Conventional	Accelerometer	Conventional	
Ueyama et al ⁶¹	2018	<i>Knee Surgery, Sports, Traumatology, Arthroscopy Journal</i>	Operation time, placement of component, asymptomatic DVT and PE	78	81	2 weeks postoperative	Operation time (minutes)	0.736
							109 ± 16	108 ± 21
							AFP (°)	
							2.7 ± 2.2	3.2 ± 1.9
							ATP (°)	0.126
							7.2 ± 4.4	6.8 ± 4.2
							CFA shifting (°)	0.558
							1.2 ± 0.9	1.6 ± 1.5
							SFA shifting (°)	0.03
							3.1 ± 1.9	3.2 ± 2.2
							CTA shifting (°)	0.759
							1.0 ± 0.8	1.2 ± 1.1
							STA shifting (°)	0.193
							2.4 ± 1.3	2.8 ± 1.7
							Asymptomatic DVT (n)	0.098
							17	19
							Asymptomatic PE (n)	0.743
							8	11
							CFA outliers (%)	0.520
							3	15
							SFA outliers (%)	< 0.01
							15	43
							AFP outliers (%)	< 0.01
							39	53
							CTA outliers (%)	0.077
							1	7
							STA outliers (%)	0.056
							12	15
							ATP outliers (%)	0.581
							81	82
								0.871

Table 3. Studies comparing accelerometer-based navigation comparing ABN with conventional TKA (continued)

Authors	Year	Journal	Study design	Follow-up		Results		p value
				Accelerometer	Conventional	Accelerometer	Conventional	
Nam et al ⁴²	2014	<i>The Journal of Arthroplasty</i>	Mechanical alignment and placement of component	47	47	Tibial resection time (minutes)	1.17 ± 0.46	< 0.001
						MA shifting (°)	0.2 ± 2.6	0.499
						CTA shifting (°)	0.6 ± 0.9	0.265
						STA shifting (°)	3.3 ± 1.5	0.79
						MA outliers (%)	10.6	0.10
						CFA outliers (%)	29.8	0.66
						CTA outliers (%)	4.3	< 0.001
						STA outliers (%)	5	0.007
Gharalbeh et al ¹⁶	2017	<i>The Journal of Arthroplasty</i>	Mechanical alignment, component placement, and operative time	89	90	Operation time (min)	77.5 ± 10	0.052
						CFA (°)	90.5 ± 1.6	0.019
						CTA (°)	90.7 ± 1.3	0.139
						STA (°)	87.9 ± 1.5	0.389
						HKA shifting (°)	1.2 ± 2	0.020
						SFA shifting (°)	2.4 ± 1.2	1
						HKA outliers (°)	13.5	0.43
						CFA outliers (%)	1.1	0.095
						SFA outliers (%)	0	2.2
						CTA outliers (%)	2.2	1.1
						STA outliers (%)	2.2	0.564

Table 3. Studies comparing accelerometer-based navigation comparing ABN with conventional TKA (continued)

Authors	Year	Journal	Study design	Follow-up		Results		p value
				Accelerometer	Conventional	Accelerometer	Conventional	
Ikawa et al ²³	2017	<i>Journal of Bone and Joint Surgery</i>	Placement of femoral component and blood loss	121	120	CFA (°)	89.7 ± 1.4	88.7 ± 2.2
					Immediate postoperative	CFA outliers (%)	0.8	15.8
						HKA shifting (°)	1.01 ± 1.0	1.93 ± 2.7
						Femoral resection time (minutes)	5.6 ± 1.9	2.9 ± 1.3
						Tourniquet time (minutes)	77.1 ± 8.5	77.5 ± 8.9
Kinney et al ³⁰	2018	<i>The Journal of Arthroplasty</i>	Mechanical alignment and placement of component	25	25	MA shifting (°)	1.92 ± 0.34	2.83 ± 0.41
					1 and 4 months postoperative	CFA shifting (°)	1.65 ± 0.17	2.23 ± 0.33
						CTA shifting (°)	1.28 ± 0.13	1.71 ± 0.24
						CFA outliers (°)	0.2	13.3
						CTA outliers (°)	0	0.4
						tourniquet time (minutes)	113.6 ± 2.5	114.3 ± 3.2

Lower extremity mechanical axis (MA) is the angle formed by the mechanical axis of the femur (line between the center of the femoral head and the center of the knee) and the mechanical axis of the tibia (line between the center of the talus and the center of the knee or hip-knee-ankle angle); coronal femoral-component angle (CFA) is the angle formed by the femoral component and the mechanical axis of the femur; sagittal femoral-component angle (SFA) is the angle between the sagittal mechanical femoral axis and a line along the posterior flange of the femoral component; coronal tibia-component angle (CTA) is the angle formed by the tibia base plate and the mechanical axis of the tibia; sagittal tibia-component angle (STA) or tibial slope or posterior slope is the angle between the sagittal mechanical tibial axis and a line through the proximal aspect of the tibial component; the accepted values used in study for normal alignment were (1) 0 ± 3° varus/valgus for MA; (2) perpendicular (± 3°) to the mechanical axis of the femur for CFA and SFA; (3) perpendicular (± 3°) to the mechanical axis of the tibia for CTA; (4) 87° ± 3° to the mechanical axis of the tibia for STA. The outlier was defined as cases in which the alignment error was > 3° from the accepted values. Shifting define as degree of deviation from MA (180°), CFA (90°), SFA (90°), CTA (90°), and SFA (87°); recent studies comparing ABN with conventional TKA; KSS = Knee Society Score; OKS = Oxford Knee Score; MCS = mental component score; PCS = physical component score; HKA = hip-knee-ankle angle; DVT = deep vein thrombosis; PE = pulmonary embolism.

ponent outliers, only one study by Ueyama et al⁵⁹ evaluated this endpoint; the authors observed no differences between the study groups.

Only one study of seven found accelerometer-based navigation superior to conventional TKA in reducing the proportion of knees that were outliers with regard to CTA⁴⁴; the other six found no between-group differences.^{17,18,31,42,58,59} Likewise, only one of five studies saw a reduced likelihood of CTA outliers⁴³, with the other four arriving at a no-difference conclusion.^{17,42,58,59} Only one study compared the proportion of outliers in axial placement of the tibial component; it showed no difference between the accelerometer-based navigation and the conventional TKA group.⁵⁹

Functional Outcome

None of the three studies that evaluated ROM found a difference between accelerometer-based navigation and conventional approaches to TKA alignment^{18,58,59}; none of the four studies that evaluated the Knee Society Score found a benefit to accelerometer-based navigation^{18,28,37,58}, and neither of the two that evaluated the Oxford Knee Score (OKS), SF36 physical component score (PCS), and SF-36 mental component score (MCS) found between-group differences, either.^{18,37}

Surgical Time, Complications, and Reoperations

In one of seven studies, surgical time was increased in the accelerometer-based navigation group compared with conventional TKA (83.9 ± 21.8 minutes versus 72.5 ± 14.6 , $p < 0.001$)³⁷; the other six did not show an increase.^{17,18,28,43,58,59}

Concerning complications, there were no differences between accelerometer-based navigation and conventional TKA using either an intramedullary, extramedullary, or a combined technique in the three studies that reported on this endpoint.^{18,28,37} No reoperations or revisions were reported in any study, but one study reported asymptomatic DVT and asymptomatic PE in the accelerometer-based navigation group (17% and 8%, respectively) and conventional group (19% and 11%, respectively).⁵⁹

DISCUSSION

The importance of better alignment in TKA derives from the apparently higher revision risk from wear and loosening that are associated with malalignment.^{12,49} Computer-assisted surgery systems (CAS) have been shown to be helpful in some studies in terms of achieving neutral alignment in the coronal plane compared with conventional TKA.^{2,4,5,6,13,15,19,29,34,39,43,58,64} However, improved component and overall limb alignment accuracy does not guarantee improved clinical and functional outcomes.^{4,9,20,40} Conventional CAS systems with large console computers are criticized because they seem to increase operative time and cost, are associated with a long learning curve^{14,16}, have

sensitive optical instruments⁶, and do not demonstrate an improvement in implant survival. Accelerometer-based navigation was introduced as a simpler and potentially less expensive alternative; it was originally used for the tibial component, but more recently it had also been used to guide the distal femoral cut.⁴³ Although previous studies have disagreed about its efficacy^{17,18,24,28,31,37,42,43,58,59}, accelerometer-based navigation is seeing wider use.^{24,28} Thus, an evaluation of the potential clinical benefits and complications of this technology compared with conventional TKA seems important. We therefore performed a systematic review to ask: (1) Is accelerometer-based navigation more accurate than conventional TKA? (2) Does accelerometer-based navigation provide better functional outcomes than conventional TKA? (3) Does accelerometer-based navigation result in increased surgical time, decreased complications and fewer reoperations compared with conventional TKA? We found very inconsistent (and generally small) benefits in favor of accelerometer-based navigation in terms of alignment, but no benefits regarding the functional outcomes or the risk of complications or reoperations. Until or unless more compelling evidence in favor of the new technology emerges, we recommend against its widespread adoption.

Several limitations of this study must be noted. First, only four RCT studies were included, and the study quality of these was only fair. Because studies with high bias risk will tend to overestimate the benefits of the new treatment, the already-small advantages in some endpoints in this review that favored accelerometer-based navigation should be considered inflated. The accelerometer-based navigation systems used were not identical, although the principles were the same, and this might influence results, however, it is difficult to say how. In some studies, accelerometer-based navigation was used only for one component (either femoral or tibial)^{24,28,43}. This probably unfairly advantaged accelerometer-based navigation, resulting in that technology looking better than it probably would if it had been used alone. This should further caution the reader that this technology seems to offer little advantage. Secondly, this is not a meta-analysis; the small number of published RCTs concerning accelerometer-based navigation precluded the statistical pooling of results (meta-analysis). Another limitation was the absence of long-term assessments of revision risk; although it is possible that over the longer term a benefit favoring accelerometer-based navigation may emerge in terms of this endpoint, the small and inconsistently observed alignment benefits of this approach make this seem unlikely.

Accelerometer-based navigation attempts to combine the accuracy of CAS with the familiarity of conventional TKA.¹⁷ Our systematic review showed that using accelerometer-based navigation improved alignment in some but not in most studies. In light of the high risk of bias, which likely inflated the apparent benefits of accelerometer-based navigation in terms of these parameters, we cannot recommend its wide adoption. One possible application that we believe deserves further study is in the knees of some Asian

patients, where femoral bowing is a problem. One study found that accelerometer-based navigation decreased the proportion of knees with outliers in terms of hip-knee-ankle alignment of more than 3° from neutral (as well as malalignments of both the femoral and tibial components)⁵⁸, although we caution against drawing firm inferences from one study, and that study did not demonstrate improvements in functional outcomes.

Several studies evaluated the clinical and functional outcomes of accelerometer-based navigation and conventional TKA, but none found accelerometer-based navigation to be superior to conventional TKA.^{18,28,37} Prior studies have suggested that improved alignment may be associated with superior patient-reported outcomes^{26,56}; however, this has not consistently been found to be the case.⁴⁷ In our systematic review, we determined that accelerometer-based navigation improved alignment but not patient-reported outcomes or ROM; the absence of differences favouring that technology over conventional TKA regarding outcome scores further confirms that any such benefits are of little importance to patients.

We found no benefit with accelerometer-based navigation concerning complications or reoperations, and one study found it increased surgical time.³⁷ A study by Parratte et al⁴⁸ showed no improvement in survival rates when the alignment reached the neutral mechanical axis $\pm 3^\circ$ when compared with the outlier group. This was a subject of controversy since previous studies had shown that neutral mechanical axis of $0^\circ \pm 3^\circ$ would improve implant durability.^{39,47} But many factors contribute to long-term TKA survivorship^{1,25,57}; a new concept of constitutional varus was introduced because 30% of individuals have constitutional varus, which may contribute to functional and long-term durability³. We found no difference in emboli, asymptomatic DVT and PE, infection, perioperative mortality, fracture, or revision.^{18,24,28,31,36,59}

We saw no consistent benefit with accelerometer-based navigation over conventional TKA in terms of alignment, and no benefit at all regarding patient-reported outcomes, ROM, complications or reoperations. The new technique may or may not add surgical time to the operation. Additionally, we note that study quality was highly variable, with most studies exhibiting a high risk of bias; this would be expected to cause an increase in the apparent benefit of the novel treatment, and so this further reinforces our conclusion that there is not enough evidence to recommend accelerometer-based navigation. Given the absence of high-quality evidence demonstrating compelling benefits of this accelerometer-based-navigation technology for patient outcomes, we recommend against wide adoption of accelerometer-based navigation in TKA.

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Chapter 6

VTE prophylaxis for hip and knee arthroplasty: changing trends

Budhiparama N.C.
Abdel M.P.
Ifraan N.N.
Parratte S.

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ABSTRACT

Venous thromboembolism (VTE) has been identified as an immediate threat to patients undergoing major orthopaedic procedures such as total hip arthroplasty (THA) and total knee arthroplasty (TKA). Given the known dangers of VTE, arthroplasty surgeons are sensitive to the need for VTE thromboprophylaxis. However, the modalities of thromboprophylaxis used to minimize the risks to patients have been variable. Clinical practice guidelines have been published by several professional organizations, while some hospitals have established their own protocols. The 2 most popular guidelines are those published by the Academy of Orthopaedic Surgeons (AAOS) and American College of Chest Physicians (ACCP), both from North America. Prior to 2012, these recommendations varied depending on underlying definitions, methodology, and goals of the 2 groups. For the first time, both groups have similar recommendations that focus on minimizing symptomatic VTE and bleeding complications. The key to determining the appropriate chemoprophylaxis for patients is to balance efficacy of a prophylactic agent, while being safe in regard to bleeding complications. However, a multimodal approach that focuses on early postoperative mobilization and the use of mechanical prophylaxis, in addition to chemoprophylaxis, is essential.

INTRODUCTION

As the number of total joint arthroplasties performed worldwide continues to grow, a commensurate increase in the number of venous thromboembolism (VTE) events can be anticipated. Although the incidences of symptomatic deep vein thrombosis (DVT) and pulmonary embolism (PE) are low, the incidence of asymptomatic DVTs has been estimated to be 20%–40% of inpatients undergoing total hip arthroplasty (THA) and total knee arthroplasty (TKA).¹ Unfortunately, the risk of symptomatic VTE has remained stable over the past 2 decades. Therefore, the use of effective and safe chemoprophylaxis agents is crucial for minimizing the risk of VTE events in these patients. Despite several decades of experience and hundreds of clinical studies, there is still no consensus on the ideal method of thromboprophylaxis for patients undergoing THA and TKA. This inconsistency has raised the concern that many patients are at risk for insufficient prophylaxis or excessive bleeding risks. In a retrospective study involving 3497 patients who had THAs or TKAs between April 1, 2004 and December 31, 2006, Selby et al found that only 40% of patients received the 8th edition American College of Chest Physicians (ACCP) recommended thromboprophylaxis.² Out of the patients receiving non-ACCP recommended prophylaxis, 81 % received shorter than the minimum 10 days recommended, making them twice as likely to experience a DVT (3.76% vs 2.01%, $P=0.003$) and more than 8 times more likely to experience a PE (1.19% vs 0.14%, $P=0.001$).

In the past 2 years, there have been remarkable changes to the clinical guidelines for VTE prophylaxis, mostly pertaining to changes in the ACCP guidelines. This review will describe the new guidelines published by the American Academy of Orthopaedic Surgeons (AAOS) and ACCP, their influences on how surgeons prescribe thromboprophylactic agents, and the currently available chemoprophylactic options.

ACCP and AAOS Guidelines

A number of concerns have been identified with the previous ACCP clinical guidelines. Until the eighth conference in 2008, prior methodologies emphasized multicenter, randomized clinical trials with venographically proven DVTs as the endpoint. The United States (US) Food and Drug Administration (FDA) recognizes venographically proven DVTs as a valid endpoint for the efficacy of VTE prophylactic drugs. This method is very expensive and often weighted toward studies utilizing aggressive pharmaceutical chemoprophylaxis. However, the vast majority of DVTs are asymptomatic. In addition, venography has been largely replaced by ultrasound (US) techniques in most major medical centers and hospitals. Moreover, the clinical significance of asymptomatic DVTs has been extensively debated. In a recent study, Parvizi et al³ found a very low correlation between the presence of DVTs and PEs, and, therefore, questioned the clinical significance of an asymptomatic DVT.

In essence, the ACCP guidelines were more focused on efficacy, often under emphasizing the risk of bleeding, which is associated with serious complications including hematoma, infection, and reoperation. Moreover, the ACCP described a major bleeding episode as overt bleeding associated with at least 1 of the following: death or life threatening clinical event; bleeding confirmed as retroperitoneal, intracranial or intraocular; transfusion of more than 2 packed units of blood cells or whole blood; or decrease of haemoglobin more than 2 g/dL compared with relevant postoperative level⁴. These criteria generally do not apply to THA and TKA patients. Galat et al⁵ reported that patients with wound complications requiring reoperation within 30 days of TKA were 10 times more likely to have subsequent major surgery and associated morbidities than those without. However, failure to meet the ACCPs strict criteria of major bleeding event resulted in under reporting of bleeding complications in many studies. Investigations by both Keeney et al⁶ and Novicoff et al⁷ revealed a dramatic increase in bleeding after adopting the ACCP protocols. Finally, not only did the orthopaedic surgeons experience an increase in bleeding, but they were also prohibited from using less aggressive and less expensive options such as aspirin with mechanical compression devices, even in young patients with a very low VTE risk.⁸⁻¹⁰

Another major concern with the ACCP guidelines was that numerous potential financial conflicts of interest were found with many authors. As a result, the Institute of Medicine issued recommendations regarding guideline development that discouraged any financial conflict of interest among its authors of clinical guidelines.¹¹

Due to the many concerns raised regarding the ACCP guidelines, the AAOS formed its DVT/PE workgroup in 2007 and issued its own recommendations by reviewing the available literature on VTE with symptomatic DVT, PE, and mortality as endpoints.¹² The goal was to achieve more balance between minimizing risk and maximizing efficacy, while minimizing conflicts of interest during the guideline development. Patients were classified based on their medical history to identify their risk of VTE and bleeding. The AAOS guidelines were in conflict with the ACCP guidelines until the ninth edition of the ACCP recommendations, which was published in 2012.¹³

In 2012 edition, the ACCP addressed almost all the concerns found in their previous clinical guidelines. Their methodology was changed dramatically to focus on more symptomatic and significant outcomes like bleeding and wound drainage. While the AAOS was unable to recommend a specific modality of prophylaxis nor the optimal duration of treatment, the ACCP recommended several choices. The conflicts of interest issue were addressed with more than half their authors declaring no potential financial conflict of interests. They also recommend a mobile intermittent pneumatic compression device (IPCD) that has a compliance monitoring chip as supported in a study by Colwell et al.¹⁴ Importantly, neither guideline could identify any literature that supported the use of IVC filters to prevent PE. Moreover, both guidelines recommended against routine US screening.

Chemoprophylaxis

VTE prophylaxis for THA and TKA patients are available in chemical and/or mechanical forms. In recent years, there has been significant progress towards developing more effective and practical thromboprophylaxis agents to include either injectable low molecular weight heparin (LMWH)¹⁵ or the latest oral anticoagulant agents (factor X inhibitors and direct thrombin inhibitors).^{16,17} Chemical prophylaxis agents included in the clinical guidelines were aspirin, warfarin, LMWH, fondaparinux, dabigatran, rivaroxaban, and apixaban. All are approved for use in United States except dabigatran and apixaban. This review will concentrate on studies that were influential to the formation of AAOS and ACCP recommendations. The following paragraphs will also describe briefly the current chemical prophylaxis suggested by ACCP guidelines and the recent available research papers.

Aspirin

Aspirin has been a popular chemoprophylaxis agent for the last three decades. It is still widely used in North America, although it is considered less available in Europe.¹⁸ The ACCP guidelines⁴ recommended aspirin as a chemoprophylaxis agent, rather than no prophylaxis at all (Grade 1B). This is due to the Pulmonary Embolism Prevention (PEP) trial,¹⁹ which concluded that low-dose aspirin, when taken for thirty-five days, would result in 7x less symptomatic DVT cases, but in three bleeding cases and two non-fatal myocardial infarctions per 1000 patients. On the other hand, AAOS guidelines recommend the use of pharmacologic agents and/or mechanical compressive devices for prevention of VTE but is inconclusive on which strategy is optimal.¹²

In a study by Vulcano et al, the rate of VTE between aspirin was compared to warfarin in adjunct to multimodal prophylaxis (i.e. early mobilization post operatively, pneumatic compression devices, and regional anaesthesia).²⁰ The results showed a lower rate of VTE, PE, proximal DVT and distal DVT for the aspirin group. However, the findings may be biased since aspirin was given to low-risk patients and warfarin was given to high-risk patients.

Unfractionated Heparin (UFH)

Heparin is one of the oldest thromboprophylaxis agents for VTE following major surgery. However, due to the inconvenient method of administration (subcutaneous injection 2-3 times a day) and an increased frequency of complications such as heparin-induced thrombocytopenia (HIT), the use of this agent has decreased in popularity. In fact, UFH is very rarely included as a studied agent in recent publications.²¹

Leyvraz et al²² studied 349 patients undergoing THA in 28 European orthopaedic departments. All patients had venograms completed 10 days after the surgery. The results showed DVT events in 16% of UFH patients and 12.6% of LMWH patients, ($p = 0.45$) and

the incidence of proximal DVT was much lower in LMWH group (2.9% and 13.1%, respectively; $p < 0.001$). Bleeding events were low and comparable between both groups.

Low Molecular Weight Heparin

Low molecular weight heparin is generated from unfractionated heparin either through physical, chemical, or enzymatic depolarization.⁴ Some of the available LMWHs are enoxaparin, dalteparin, and tinzaparin. Among these three, only two (enoxaparin and dalteparin) are indicated in major orthopaedic surgery.²³

A meta-analysis study involving 16 randomized controlled trials (RCTs) compared enoxaparin with the newer anticoagulants (rivaroxaban, dabigatran, apixaban).²⁴ The study concluded that newer anticoagulants are higher in efficacy, but also have higher risk of bleeding. The risk of symptomatic VTE was lower with rivaroxaban (relative risk [RR] 0.48, 95% confidence interval [CI] of 0.31 to 0.75), and similar with dabigatran (RR = 0.71, CI 0.23 to 2.12) and apixaban (RR = 0.82, CI of 0.41 to 1.64). In terms of safety outcome, rivaroxaban was associated with a significant increase in the risk of clinically relevant bleeding (RR = 1.25, CI of 1.05 to 1.48; $p = 0.01$). Dabigatran did not show a significant increase compared to enoxaparin (RR = 1.12, CI of 0.94 to 1.35; $p = 0.21$), regardless the dosage used (150 mg or 220 mg). However, this study found that apixaban was associated with a significant reduction in risk of bleeding (RR = 0.82, CI of 0.69 to 0.98; $p = 0.03$). On the same paper, after balancing efficacy and safety (symptomatic DVT or PE with clinically relevant bleeding events), no significant difference was found between LMWH and newer anticoagulant agents. However, it is important to note that all papers reviewed in this meta-analysis were sponsored by pharmaceutical companies.

Another review tried to compare indirectly between dalteparin and enoxaparin as prophylaxis in patients following THA.²⁵ From nine RCTs that were studied (all compared to placebo), results demonstrated comparable safety and efficacy between these two LMWHs. Both have 50% risk reduction of VTE compared to placebo (RR = 0.50, $p < 0.001$) and no increase in major bleeding (RR = 1.19, $p = 0.76$), heparin induced thrombocytopenia (RR = 1.13, $p = 0.83$) or death (RR 0.72, $p = 0.59$). Although this study showed similar efficacy and safety between enoxaparin and dalteparin, more RCTs comparing these two agents are needed to actually see the difference.

One of the older reviews²⁶ compared the cost-effectiveness between enoxaparin and warfarin for DVT prophylaxis following THA. The study showed that the occurrence of DVT was lower in the enoxaparin group (13.6%) compared to warfarin group (20.6%). In ACCP guidelines⁴, the single most suggested thromboprophylactic agent was LMWH, unless patients had a high risk for bleeding or were uncooperative with injections.

Warfarin

Warfarin is a vitamin K antagonist and has been widely used in United States as an anticoagulant agent since 1954 for various indications.²⁷ It derived its name because it was discovered at the University of Wisconsin (WARF = Wisconsin Alumni Research Foundation). It was the first oral anticoagulant. However, the usage is restricted by the bleeding risk, potential drug interaction, and requirement for constant monitoring (INR). Warfarin has been compared to low molecular weight heparin (LMWH) as prophylaxis for TKA in several multicenter clinical trials.²⁸⁻³² To summarize, all studies showed that LMWH was a more effective agent to prevent DVT formation ($p < 0.05$), but no difference to warfarin in preventing symptomatic events including PE, in part since most of studies measured primary outcome as asymptomatic DVT. Moreover, LMWH resulted in more bleeding episodes compared to warfarin, although the difference is not significant ($p > 0.05$).

Factor Xa Inhibitor (*fondaparinux, rivaroxaban, apixaban*)

There are two types of factor Xa inhibitors, the indirect and direct. Fondaparinux and idraparinux are examples of indirect factor Xa inhibitors. They are synthetic, highly selective factor Xa inhibitors that work in a pentasaccharide form. However, the development of idraparinux was terminated due to prolonged elimination half-life and increased risk of bleeding longer than six months. On the other hand, direct factor Xa inhibitors work by binding to the active site of factor Xa, thus blocking the interaction with its substrate.³³⁻³⁵ Examples of oral direct factor Xa inhibitors are rivaroxaban, apixaban, edoxaban and betrixaban.³⁵ Rivaroxaban and apixaban are recommended by the ACCP in the same manner as the fondaparinux.⁴ However, the increase in efficacy is accompanied by an increased bleeding risks, which is why LMWH remains the most recommended chemoprophylaxis.¹³

A multicenter RCT from Japan studied the effect of fondaparinux compared to placebo and the dose-response effect (0.75 mg, 1.5 mg, 2.5 mg and 3.0 mg) in patients with TKA or THA (two separate sub-studies).³⁴ In the TKA sub-study, the incidence of VTE was 34.2%, 21.3%, 16.2%, and 9.5% in groups receiving fondaparinux 0.75mg, 1.5mg, 2.5mg and 3.0mg respectively, compared to the placebo group (65.3%). In THA sub-study, the incidence of VTE was 24.2%, 4.6%, 7.4%, and 14.4%, compared to the placebo group (33.8%). In both sub studies, each group receiving fondaparinux showed significant reduction in asymptomatic VTE events compared to placebo ($p < 0.001$), while no major or minor bleeding difference was found between the fondaparinux and placebo groups. Turpie et al³⁶ completed a meta-analysis on VTE prevention between fondaparinux and enoxaparin in patients undergoing elective major orthopaedic surgery (THA, TKA, and ORIF of hip fractures). The result showed greater reduction of VTE events in the fondaparinux groups (6.8%) compared to enoxaparin (13.7%), and the result was

consistent in all studies reviewed. Despite more major bleeding events that occurred in the fondaparinux group ($p = 0.008$), clinically relevant bleeding that led to death or occurred in critical organs did not differ between the two groups. According to ACCP recommendation⁴, fondaparinux is suggested as chemoprophylaxis agent in patients undergoing THA or TKA, but its use needs thorough judgment based on the patients' bleeding risks and is positioned with a lower recommendation than LMWHs. Therefore, due to bleeding concerns, the use of fondaparinux in North America is not as popular as other VTE prophylaxis for arthroplasty.³⁷

Rivaroxaban

Rivaroxaban is an FDA approved oral direct factor Xa inhibitor that also requires no monitoring. There have been four Phase III randomized trials³⁸⁻⁴¹ to assess the efficacy of rivaroxaban as a VTE prophylaxis agent in total joint arthroplasty patients. Lassen et al³⁸ showed that 10 mg of rivaroxaban taken once daily was more effective than 40 mg of enoxaparin administered once daily in reducing overall VTE for TKA patients (RR = 9.2%, $p < 0.001$). There was no difference in major bleeding between rivaroxaban and enoxaparin groups (0.6% vs. 0.5%; $p >$

0.05). In a different study comparing 10 mg of rivaroxaban once a day with 30 mg enoxaparin every twelve hours in TKA patients, Turpie et al³⁹ found the rivaroxaban group yielded a lower overall VTE incidence and mortality rate compared to enoxaparin group (absolute risk reduction 3.19%, 95% CI 0.71-5.67; $p = 0.0118$). No difference in major bleeding events between both group (0.7% vs 0.3%; $p = 0.109$). In the latest retrospective review, Jensen et al⁴² associated rivaroxaban with more re-operations than LMWH after TKA (3.94% vs. 1.8%; $p = 0.046$).

In a study comparing 10 mg of rivaroxaban taken six hours post-operatively against 40 mg enoxaparin administered the evening pre-operatively as prophylaxis for THA, Eriksson et al found rivaroxaban to be significantly more effective than enoxaparin in preventing total VTE (1.1% vs. 3.7%, RR of 2.6%, $p < 0.001$) but not in symptomatic events (96.8% vs 97.0%; $p > 0.05$). No difference in occurrence of major bleeding ($p = 0.18$).⁴⁰

In another study comparing usage of ribaroxaban with extended duration of thirty-five days against administration of enoxaparin for ten to fourteen days, Kakkar et al found rivarovaban to be significantly more effective than enoxaparin in limiting total VTE and symptomatic episodes (RR = 7.3%, CI of 5.2 - 9.4; $p < 0.0001$). No significant difference on any bleeding during treatment ($p = 0.25$).⁴¹ The current controversy for rivaroxaban is the timing of first dosage. In the above-mentioned four studies, rivaroxaban was administered six to eight hours postoperatively, but it may be safer to start the first dosage the next day especially if the drug does have any effect on the development of symptomatic events.

Studies to date may not have found significant differences in adverse event between direct factor Xa inhibitors and LMWH, but direct factor Xa inhibitors do have a bleeding risk that is still higher than LMWH. Lassen et al⁴³ conducted an analysis from four phase III clinical trials (i.e. RECORD 1-4 [Regulation of Coagulation in Orthopaedic Surgery to prevent deep venous thrombosis and pulmonary embolism]). These trials involved 12,383 patients undergoing THA or TKA which then randomized to receive either oral rivaroxaban 10 mg once daily or subcutaneous enoxaparin 40 mg once daily (RECORD 1-3) or enoxaparin 30 mg twice daily (RECORD 4). The adverse event was observed only during the active treatment period. These studies showed that patients who underwent TKA have more complications compared to THA patients despite the types of prophylaxis given. Moreover, although the number of bleeding events were higher in rivaroxaban treatment groups, the difference was not significant. This can be one of the reasons rivaroxaban has been approved in more than 115 countries worldwide for the prevention of VTE after TKA or THA.

Apixaban

Apixaban is a direct oral factor Xa inhibitor that has not been approved by FDA in United States. Lassen et al⁴⁴⁻⁴⁶ conducted a series of studies comparing apixaban against different doses of enoxaparin as prophylaxis for total joint arthroplasty patients. For TKA patients, when 2.5 mg of apixaban taken twice daily was assessed against 30 mg of enoxaparin administered twice daily, both groups showed extremely low overall VTE rates, but apixaban resulted in significantly less bleeding risk.⁴⁴ In another study where 2.5 mg of apixaban taken twice daily was compared against 40 mg of enoxaparin administered once daily, Lassen et al found the overall VTE and mortality rate to be significantly lower in the apixaban group.⁴⁵ There was no significant difference found between the two groups in terms of non-major bleeding risks. For THA VTE prophylaxis, when 2.5 mg of apixaban was taken twice a day had been compared to 40 mg enoxaparin taken once daily by Lassen et al, results showed that apixaban was more effective in lowering overall VTE events and mortality rate.⁴⁶ The same study showed that with every 147 patients, apixaban prevented one VTE event without any additional bleeding risk. These three studies suggested that 2.5 mg of apixaban taken once daily is the more effective prophylactic agent when compared to 40 mg of enoxaparin administered once daily but showed the same efficacy when comparing 30 mg of enoxaparin administered twice daily. A meta-analysis performed by Russell et al to investigate the efficacy of 2.5 mg of apixaban or 10 mg rivaroxaban against enoxaparin as prophylaxis after total hip and knee arthroplasty summarized that oral factor Xa inhibitors were superior to enoxaparin in preventing DVT, but there was no difference in the rate of PE, mortality, or post-operative wound infections.⁴⁷

Direct Thrombin Inhibitor (dabigatran)

Direct thrombin inhibitors (DTIs) work by binding specifically to the active center of thrombin and inactivate free and fibrin-bound thrombin. This process is reversible leaving small amount of free and active thrombin to control hemostasis.³⁵

Dabigatran is the first oral DTI approved for the chemoprophylaxis following major orthopaedic procedures. It was first approved by Health Canada and European Medicines Agency in 2008 and is now available in more than 75 countries. It has the benefit of oral administration, being highly specific, a reversible effect, not require monitoring, and having a slow onset. Thus, the haemostatic process may take place after procedures and before the effect of anticoagulant commences.⁴⁸ In the US, dabigatran etexilate is an FDA approved oral direct thrombin inhibitor for prevention of atrial fibrillation and stroke, but not for VTE prophylaxis after THA and TKA.

A trial by Eriksson et al⁴⁹ compared dabigatran against enoxaparin (oral dabigatran 220 mg, oral dabigatran 150 mg, subcutaneous enoxaparin 40 mg; all once daily). Efficacy outcomes measured were symptomatic DVT, venographic DVT, and/or symptomatic PE. The safety outcome measured was bleeding events during the course of study. The result showed efficacy outcome (total VTE and death) of 37.7%, 36.4%, and 40.5% for enoxaparin, 220 mg dabigatran, and 150 mg dabigatran, respectively. The major bleeding occurrence also did not differ significantly among three groups (1.3% vs. 1.5% vs 1.3% respectively; $p > 0.05$).

Ginsberg et al⁵⁰ also found both doses of dabigatran to be comparable to 30 mg of enoxaparin taken twice daily in terms of bleeding episodes for total knee arthroplasty patients. Based on the above trials, ACCP concluded that dabigatran was comparable to enoxaparin/LMWH in terms of efficacy and bleeding risks.

Mechanical Prophylaxis

Mechanical prophylaxis is any compressive device applied to an affected limb. It can be a compressive stocking, IPCD, or similar working devices. A single center study conducted in Stockholm reported no significant difference in VTE incidence in 5,310 THA and TKA patients after discontinuing the use of postoperative compression stockings. The incidence was 2.7% and 2.3% ($p = 0.4$) before and after the cessation, respectively.⁵¹ ACCP guidelines suggest the use of IPCD be at least 18 hours a day as an adjunct to chemoprophylaxis, or in patient with high risk of bleeding.¹³ The AAOS guidelines recommend use of mechanical compressive devices in patients with known bleeding disorders, such as haemophilia or active liver disease or as with chemoprophylaxis in patient with previous VTE.¹²

Intermittent pneumatic compression devices

Some studies have found that mechanical prophylaxis such as IPCDs are quite effective in reducing the risk of DVT and PE in arthroplasty patients by more than 50% without any risk for bleeding. However, in the past, patients' treatment ceased upon discharge from hospital and adherence to routine application became a challenge. Therefore, the introduction of portable, battery-powered devices allows patients to utilize these devices in the hospital or at home. Moreover, a monitoring chip implanted in the device helps monitor a patient's compliance. Colwell et al¹⁴ showed in a multicenter randomized controlled trial comparing IPCD against enoxaparin that IPCD was just as effective as enoxaparin in preventing proximal and distal DVT and PE events, but resulted in a much lower bleeding risk (1.3% IPCD vs 4.3% LMWH). There was no difference in mortality rate. As a side note, this paper disclosed that one or more of its authors or immediate family received benefits from the commercial party.

Combined Modalities

Combined prophylactic modalities have been shown to improve the efficacy.^{52,53} However, it is still unclear whether this advantage also applies to total joint arthroplasty, whether the combined modalities are indeed better than either chemoprophylaxis or mechanical compression device alone, or whether they can prevent pulmonary emboli. In a systematic review and meta-analysis of 1399 patients, Kakkos et al⁵⁴ found that in TKA, the rate of DVT was reduced from 18.7% with anticoagulant alone to 3.7% with combined modalities (RR = 0.27; $p = 0.03$). For THA, the rate of DVT was reduced from 9.7% with anticoagulant alone to 0.9% with additional intermittent mechanical leg compression (RR = 0.17; $p < 0.001$). However, when anticoagulant was added to compression compared to compression alone, the rate of DVT was insignificantly reduced from 8.7% to 7.2% for THAs, but no data was available for the TKA group. Further research with a larger population on the role of combined modalities of thromboprophylaxis in total joint replacement and in other high-risk orthopaedic surgeries is needed.

Duration

The ACCP guidelines recommend a minimum of 10 to 14 days of prophylaxis in patients undergoing THA or TKA. However, it suggests extending the thromboprophylaxis to 35 days in the outpatient period (Grade 2B).¹³

Conflicts of Interest

With so many choices of thromboprophylaxis currently available on the market, orthopaedic surgeons have to be cautious when deciding the most suitable prophylaxis for their patients. The AAOS and ACCP guidelines, current literature, and individual needs of

each patient must be taken into consideration. Moreover, when reviewing study results for each modality, one has to be aware of any potential financial conflicts of interest. A recent evidence-based review by Lee et al revealed that out of seventy-one eligible studies identified, fifty-two were industry funded, fourteen were not and the remaining five did not disclose the source of funding.⁵⁵ Most of these industry-sponsored studies were performed in Western countries. The review further showed a significant correlation between the funding source and qualitative conclusions. Only 3.8% of the fifty-two industry-sponsored studies had unfavourable conclusions, whereas 21.4% of the fourteen non-industry-sponsored studies indicated that the modality examined were neither effective nor safe. Since more studies are sponsored by industry than not, one will find more favourable conclusions to the use of the sponsored prophylactic agents or recommendations for extended use. The limitation to the review by Lee et al is that the number of non-industry-sponsored studies were small, and therefore the authors' analysis was sensitive to the conclusions of those studies. In another study to evaluate thromboembolic complications after fast-track THA and TKA, Husted et al found that if patients were mobilized within 4 hours after surgery and given prophylaxis for one to four days duration, no DVT, PE, or mortality was found in the study.⁵⁶ The authors also questioned whether extended prophylaxis was actually needed when patients were mobilized early since the majority of studies on extended prophylaxis were partly sponsored by pharmaceutical companies.

Asian Perspective

There are large variations in reported cases of postoperative DVT after THA and TKA in Asian populations, even within the same country. The general consensus is that the rates are lower in Asia as compared to Western countries.⁵⁷⁻⁶¹ However, due to lack of reported data which leads to substantial under-estimation of VTE incidence, this consensus is debatable.^{62,63} However, several multicenter study such as the SMART (Surgical Multinational Asian Registry in Thrombosis), AIDA (Assessment of the Incidence of Deep Vein Thrombosis in Asia), and Asia Pacific Thrombosis Advisory Board stated that the incidence rates of DVT in Asian populations are similar compared to the Western.^{64,65,66} The paucity and variation in available data regarding the incidence of DVT in arthroplasty patients makes it difficult to prepare guidelines and protocols for thromboprophylaxis.^{64,65} The variations in data can be due different methods of detection, different designs of studies, lack of patients incidence data, and different lifestyles and dietary content. Despite declaration of minimal incidence of DVTs, developed Asian countries such as Korea, Japan, and China have established their own guidelines. This shows some consensus that clinical protocols and guidelines are necessary for each country regardless of the actual incidences reported. In addition, these guidelines can differ due to poor understanding of risk factors like ethnicity and genetic susceptibility.

CONCLUSIONS

The number of arthroplasties performed worldwide continues to increase annually. VTE remains a clinical concern due to the risk of symptomatic VTE and fatal PE. For the first time in history, the AAOS and ACCP are mostly in alignment in their latest recommendations. Both guidelines now focus on symptomatic events and bleeding risks. There should be a balance between efficacy and safety because inappropriate anticoagulation results in excessive bleeding. There are still limitations in the published guidelines that represent the limitations in the current literature. Further research is needed to identify patients at risk of VTE and bleeding. The final decision on ideal thromboprophylaxis remains with the treating physician who is most familiar with each patient's unique medical history. The current clinical guidelines provide an orthopaedic surgeon with more latitude, and choices of VTE prophylaxis without emphasis on aggressive chemical, and often unneeded, prophylaxis. Modern arthroplasty advocates early postoperative mobilization and use of mechanical prophylaxis in combination with chemoprophylaxis. The key to determining the appropriate chemical prophylaxis for patients is to balance safety and efficacy while minimizing bleeding.

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Art work by Nasirun

Chapter

7

General discussion and summary

Total knee arthroplasty is a common surgery done by orthopaedic surgeon in symptomatic end-stage knee osteoarthritis, which debilitates patients in their functionality. TKA procedures have been more increasingly performed worldwide, especially in developing Asian country such as Indonesia. Despite numerous innovative methodological and sophisticated technological advancements in TKA, approximately 20-25% of all patients undergoing particular surgery reported dissatisfaction. Several reasons can be accountable for this, such as implant design, surgical technique, patient selection, as well as patients perception (cultural background, expectations on outcome). Focus areas for improvement which are addressed can be distinguished in improvement of surgical skills, and decision making on which patient needs surgery, what should be considered in TKA. More specifically is whether there are any differences in outcome based on the background of patients, especially in Asian patients living in Asia.

Patients satisfaction on outcome after TKA is influenced by patient factors, surgical factors, and postoperative complications. Pre-operative planning, surgical technique, and implant choice play an important role in patient satisfaction. Having a good implant-bone fit and avoid overhang will increase implant survival and patient satisfaction. Every knee is unique: the shape, contour, and size. Characteristics of individual knee are different between races which, in turn, could influence the compatibility between the bone and implant in terms of TKA procedure. For that matter, anthropometry of the knee in relation to implant size is important. A retrospective study was done to evaluate differences in anthropometric dimensions between Indonesian Asian and Dutch Caucasian TKA patients with respect to sizes of nine TKA systems (Vanguard, Genesis II, Persona -standard and narrow-, GK Sphere, Gemini, Attune -standard and narrow-, and Sigma PFC) (**chapter 2**). Radiographic anthropometric data on distal femur, proximal tibia, and patellar dimension were measured in 67 Caucasian and 67 Asian patients matched for age and gender. In anterior-posterior dimension (AP) and medial-lateral dimension (ML), the Caucasian femur and tibia are larger than the Asian, but the aspect ratio (ML/AP) is larger in Asian patients compared to Caucasian patients (both tibia and femur). The Asian patients have a relative patella baja compared to the Caucasians. Overall, the smallest sizes in the Asian patients could not be matched with any of the nine knee systems. To achieve an optimal fit knee-implant, the knee systems should be available in a wider range of sizes (i.e. more smaller sizes). With respect to the fit of the implant to the natural knee, total knee arthroplasty remains a compromise to nature. Implant overhang may cause over-voluming and popliteus tendon impingement and these might result in persistent postoperative pain, which leads to deteriorating patient's satisfaction. Therefore, pre-operative planning (implant sizing and implant type) should be done in TKA. Implant sizing preoperative and intraoperatively is a must to avoid overhang and to achieve implant-bone fit.

Although patient's perception and expectation of TKA is subjective, it is very important to address and to optimize when a TKA is indicated. Cultural background of patients may be of influence on perception and expectation on outcome of TKA. Cultural differences between continents, may also affect differences in outcome on interventions. For that matter we performed a comparison study between Asian and North American population (**chapter 3**). A retrospective study compared an Asian (76 patients) and North American (64 patients) cohort of total knee replacement (TKR) patients. Demographics, patient recorded outcomes scores (KSS, PAQ, WOMAC), knee range of motion (ROM), and radiographic component position were compared. The Asian cohort had significantly worse preoperative range of motion, worse KSS function score, and worse PAQ pain scores compared to the North American but preoperative KSS knee score and WOMAC scores were comparable between the two groups. Postoperatively, WOMAC and KSS knee score were better in Asian compared to North American while KSS function and PAQ were comparable between groups. Even though Asian TKR patients had significantly worse preoperative scores, their postoperative outcomes were comparable to North Americans. The higher preoperative functional deficit and the higher pain levels in the Asian population might be due to cultural differences and/or socio-economic reasons. The latter is probably the reason why Asian patients present with more severe conditions in the preoperative consultation for a possible surgical treatment compared to North Americans. More research is needed to investigate the difference between these cultural impacts, which also exist within the same country, even more between different continents, on TKA outcomes.

Beside those patient-associated factors, surgical technique is similarly important. All surgeons are urged to improve their surgical technique. Classical surgical techniques (gap balancing technique and measured resection technique) have been developed. Another technique, hybrid technique, combining the gap balancing and measured resection technique was also generally used. But none of those technique is superior than the others and still in debate. Another consideration is resurfacing or not resurfacing the patella. Anterior knee pain (AKP) after TKA may be an important reason for patient dissatisfaction. Both advocates and opponents arise regarding resurfacing or not resurfacing the patella. The advocates found that AKP will decrease with resurfacing patella, but opponents proved that the incidence of AKP was similar with or without patellar resurfacing. Some surgeons prefer to do secondary patellar resurfacing in unresurfaced patella of TKA to treat AKP postoperatively without considering the actual cause of AKP itself. Another technique to reduce AKP is with thermal lesion to the peripatellar soft tissue. Patellar electro-cauterization is believed to denervate patellar so it might reduce efferent pain signals. Theoretically it should decrease AKP. But this theory should be proven clinically. We performed a prospective study to investigate whether there is any difference in knee pain relief, functional outcomes, and complications between

intraoperative circumferential cauterized and non-cauterized patella on unresurfaced simultaneous bilateral TKA (**chapter 4**). Seventy-three patients (146 knees) were included in this study with TKA performed by a single experienced surgeon using cruciate retaining prosthesis and fixed bearing insert. Circumferential patellar cauterization was performed on the right knee regardless of severity of the arthritis while the left patella was treated with debridement and osteophytes excision without cauterization. Evaluations were done with minimum of 2-years follow up by assessing ROM, VAS, KOOS score, OKS, Kujala Anterior Knee Pain score, and complications. No differences were found in demographic and clinical preoperative characteristics and radiologic severity (Kellgren-Lawrence grading) between the groups. Mean ROM, VAS, KOOS, OKS, and Kujala knee score were improved after surgery in both groups. However, no differences in knee pain, functional outcomes, and complications were found between circumferential cauterized and non-cauterized patella in unresurfaced simultaneous bilateral TKA at minimum of 2 years follows up. Our study here is an important piece of evidence that patellar denervation did not provide any significant benefit in reducing the AKP after TKA.

Alignment in TKA and its effect on outcome is also in debate. Two methods of alignment are used in TKA to achieve neutral alignment of the knee: anatomical alignment and mechanical alignment. Neither is superior but the majority of surgeons believe that mechanical alignment is superior. Both studies proved no difference in functional outcome exist between anatomical and mechanical alignment. However, it has recently been demonstrated with RSA (micro movements of the knee prosthesis in the bone) that a varus state (also with constitutional preop varus) causes more knee prosthesis migration. The latest alignment method introduced is kinematic alignment. Kinematic alignment aims to restore native pre-arthritic alignment as well as good ligament balancing which is highly dependent on inter-individual. The normal native knee has a constitutional alignment, being either varus or valgus, within 3 degrees of error. Using kinematic alignment claimed that it is more likely to achieve this native joint alignment even in constitutional varus or valgus aligned knees.

The importance of prosthetic alignment is also influenced by the precision of the bone resection, with either alignment technique. To improve this knee alignment goal and thus prosthetic alignment, intraoperative instruments are developed. Computer-assisted surgical (CAS) navigation was developed to accommodate this, but studies found several shortcomings (bulky, expensive devices) and no difference in functional outcome compared with conventional TKA. Therefore, patient-specific instrumentation (PSI) was introduced but also yielded no different functional outcome compared with conventional TKA. To answer the shortcomings of CAS and PSI, accelerometer-based navigation was introduced. It is a handheld navigation, single-use, sterile device used within the operative field to determine the hip center of rotation and the femoral mechanical axis. It guides the resection at the appropriate coronal and sagittal planes

and validates the alignment accuracy and confirms placement of the femoral and tibial component. A systematic review to compare the accelerometer-based navigation with conventional TKA was done (**chapter 5**). Four randomized control trials with fair to better quality were included and six non-randomized studies also with fair and better quality were included. Conflicting evidence of accelerometer-based navigation in reducing implant and alignment outliers, with no improvement in patient-reported outcomes or reduction of complication were found. We recommend not to widely adopt the use of accelerometer-based navigation until proven otherwise. Even with the newest surgical technique, no significant functional improvement was found compared with conventional TKA. But the big question arises regarding the best alignment in TKA. Which is the best alignment, anatomical alignment, mechanical or kinematic alignment? How many degrees of alignment deviation is acceptable and how to evaluate soft tissue balancing in TKA?

Finally, we addressed one of the major postoperative complications in TKA. Many factors influence the incidence of complications. Body mass Index (BMI), age, and bilateral procedures increase the incidence of complications. A BMI ≥ 30.0 kg/m², age ≥ 80 years, and bilateral procedure were significant risk factors for systemic complications, whereas a BMI ≥ 30.0 kg/m² is a risk factor for post-operative DVT. Venous thromboembolism (VTE), i.e. deep vein thrombosis (DVT) or pulmonary embolism (PE), is the third most common cardiovascular disease and occurs in 1-2 per 1000 person per year in the general population. Of all patients with VTE, around two thirds are diagnosed with DVT and one third with PE. In order to minimize this risk, VTE prophylaxis becomes a must in TKA, although we do not exactly know which patient is in need for (prolonged) prophylaxis. A multimodal approach, using chemical and mechanical prophylaxis with early post-operative mobilization, are essential in VTE prophylaxis (**chapter 6**). Chemoprophylaxis agents used in VTE prophylaxis are aspirin, warfarin, LMWH, fondaparinux, dabigatran, rivaroxaban, and apixaban. The key to determine appropriate chemoprophylaxis agents is to balance its efficacy with its risk of bleeding complication and to combine it with mechanical prophylaxis in a patient specific mode.

Future research focuses on how to improve patient's satisfaction by either optimizing patient factors, improve surgical factors (such as how to evaluate tissue balancing using intra-operative equipment, how to improve component alignment), or optimizing post-operative care (such as how to reduce postoperative pain, improve rehabilitation, and minimize postoperative complication). These studies should be based on Indonesian population from an Implant Registry in Indonesia. In the end, "no surgical innovation without evaluation" is the only way to improve outcome for our patients.

Future Recommendation

More high-quality studies are needed to improve not only implant survival but also patient's satisfaction and functionality. Furthermore, decreasing postoperative complications needs (inter)national collaboration and is a must in any medical field. For that matter, the IDEAL collaboration, no innovation without evaluation sets the standard. International guidelines, with national adaptations, will assist surgeons in better decision making for their patients. A new implant design that accommodates the anatomical features of Asian patients or even 3D printed implants might improve outcomes. But even for 3D printed implants, it holds that there is no innovation without evaluation.

Possible future research can focus on:

- Surgical level
 - o Development of an implant registry for Indonesian Hip & Knee and interpreted by orthopaedic surgeons. This system can give feedback to the surgeons on the outcome of their surgery
 - o Training of surgeons, junior and senior alike when they use a new implant in skills labs thus reducing complications
- Patient level
 - o Development of PROMs which are specific for Indonesian patients
 - o Patient's expectation management
 - o Improved pain management
 - o Improved rehabilitation for OA
- Implant level
 - o 3D printed implant and feedback on the ligament balancing based on machine learning data or artificial intelligence can be used to give intraoperative feedback to the surgeon
 - o High-quality low-cost generic implants will become available, implants are becoming a commodity

Conclusions

Up to date, there are insufficient data to create evidence-based results for the TKA technique. Level 1 evidence-based studies are required to create recommendations and guidelines to increase health care in TKA. Besides, in choosing the best operative technique and implant, evidences are also needed (both basic science and clinical) and should not be market driven. As for all medical disciplines: no innovation without evaluation, as patient's safety and outcome are of paramount importance.



Art work by Nasirun

Chapter 8

Nederlandse samenvatting

Totale knie arthroplastiek (TKA) is een veel voorkomende operatie uitgevoerd door orthopedisch chirurgen bij ernstige invaliderende klachten van een eindstadium van radiologische knie artrose. Ondanks het toenemende aantal TKA-patiënten zijn nog steeds 20-25% van de patiënten ontevreden na deze operatie. Hiervoor zijn verschillende redenen verantwoordelijk zoals, implantaat ontwerp, chirurgische techniek, patiënt selectie, maar ook de perceptie van patiënten (culturele achtergrond, verwachtingen) over de uitkomst na operatie. Aandachtsgebieden om de uitkomsten na TKA voor patiënten te verbeteren kunnen worden onderscheiden in type implantaat, methoden ter verbetering van chirurgische vaardigheden, besluitvorming over welke patiënt chirurgie of een conservatief beleid nodig heeft, en patiënt's verwachtingen met betrekking de verwachte uitkomst van een behandeling. Specifieker is of er verschillen in uitkomst zijn op basis van de achtergrond van patiënten, vooral bij Aziatische patiënten die in Azië wonen.

De tevredenheid van patiënten over de uitkomst na TKA wordt beïnvloed door patiënt factoren, chirurgische factoren (techniek en implantaat) en postoperatieve complicaties. Technische aspecten zoals preoperatieve planning, chirurgische techniek en implantaat keuze zijn de klassieke onderwerpen die een belangrijke rol spelen bij de uitkomst na een TKA en dus ook de patiënt tevredenheid. Het hebben van een goede implantaat-gewricht pasvorm, zonder dat het uitsteekt buiten tibia of femur of dat de componenten te klein zijn, verminderd niet alleen de klachten bij patiënten, maar verminderd ook de kans op loslating. In dat kader, is het belangrijk of de op westerse mensen ontworpen knieprothese ook een optimale passing heeft bij Aziaten in Indonesië. Hiervoor werd een retrospectief onderzoek gedaan om verschillen in de antropometrische dimensies te evalueren tussen de Indonesische Aziaten en Nederlandse westerse TKA-patiënten met de dimensies van negen TKA-systemen (Vanguard, Genesis II, Persona-standard en Persona-narrow, GK Sphere, Gemini, Attune-standard en Attune-narrow en Sigma PFC) (**hoofdstuk 2**). Radiologische metingen van het distale femur, proximale tibia en de patella werden gemeten in 67 Aziatische patiënten, die gematched waren qua leeftijd en geslacht met 67 westerse Nederlandse patiënten. In anterieure-posterieure dimensie (AP) en mediale-laterale grootte (ML) is het distale femuren de tibia groter bij Nederlandse patiënten groter dan bij de Indonesische Aziaten, echter de verhouding tussen beide (ML/AP), de dimensie is groter bij de Aziatische, zowel tibia als femur. De Aziatische patiënten hebben een relatieve patella baja in vergelijking met de westerse. Over het algemeen konden de kleinste maten bij de Aziatische patiënten niet worden geëvenaard met een van de negen knie systemen. Gezien de kleinere dimensies die bij patiënten aanwezig kunnen zijn, (evenals extreem grote dimensies) zullen kniesystemen die uiterste maten meenemen in hun productlijn, zorgen dat er een optimalere passing ontstaat van het implantaat. Patiënt specifieke plaatsing zal leiden tot een betere uitkomst. Uiteindelijk blijft het verrichten van een totale knie arthroplastiek altijd

een compromis met de natuur, niet alleen qua vorm maar vooral met betrekking tot de biomechanica.

Hoewel de perceptie en de verwachting van TKA subjectief zijn, is het zeer belangrijk om deze te optimaliseren wanneer een TKA wordt aangegeven. De culturele achtergrond van patiënten kan van invloed zijn op deze perceptie en verwachting van de uitkomst na TKA. Culturele verschillen tussen verschillende continenten kunnen ook invloed hebben op verschillen in de uitkomst van interventies. Daarom hebben we een vergelijking studie uitgevoerd tussen een Aziatische en een Noord-Amerikaanse TKA patiënten groep (**hoofdstuk 3**). Het betrof een retrospectieve studie waarbij een Aziatische (76 patiënten) en een Noord-Amerikaanse (64 patiënten) patiëntengroep een TKA kreeg van hetzelfde type. Demografische gegevens, patiënt uitkomst scoren, zogenaamde PRO (patient reported outcome) waren hetzelfde in beide groepen. De scoren die gebruikt werden zijn gewrichten specifiek en betreffen pijn en functie (KSS, PAQ, WOMAC), knie beweging (range of motion) en radiologie (i.e. stand postoperatief van de prothese). Het Aziatische cohort had een aanzienlijk slechtere preoperatieve kniefunctie, KSS-functie Score, en een hogere PAQ pijn (meer pijn) scores in vergelijking met de Noord-Amerikaanse patiënten. De preoperatieve KSS knie Score en WOMAC scores waren vergelijkbaar tussen de twee groepen. Postoperatief, waren de WOMAC en KSS knie Score beter (dus meer functie) in de Aziatische in vergelijking met de Noord-Amerikaanse patiënten, terwijl de KSS-functie en PAQ pijn vergelijkbaar waren tussen groepen. Hoewel Aziatische TKA-patiënten een significant slechtere preoperatieve score hadden, waren hun postoperatieve uitkomsten vergelijkbaar met Noord-Amerikanen. De slechtere preoperatieve functie en de hogere pijn score in de Aziatische populatie kunnen te wijten zijn aan culturele verschillen en/of sociaaleconomische redenen. Dit laatste is waarschijnlijk een reden waarom Aziatische patiënten laat vooreen preoperatieve consultatie voor een mogelijke chirurgische behandeling komen in vergelijking met Noord-Amerikanen. Er is meer onderzoek nodig om het verschil te onderzoeken van deze mogelijke culturele en sociale oorzaken. Deze kunnen ook binnen een zelfde land bestaan, afhankelijk van zorg systemen, maar ook tussen verschillende continenten.

Naast deze patiënten factoren is de chirurgische techniek belangrijk. Alle chirurgen worden aangespoord om hun chirurgische techniek te verbeteren. Klassieke chirurgische technieken (Gap Balancing techniek en gemeten resectie techniek) zijn ontwikkeld in de loop der jaren. Een andere techniek, hybride techniek, combineert de knie uitbalanceren en gemeten resectie techniek. Maar geen van deze technieken is bewezen superieur aan de ander, er bestaat nog steeds discussie. Een andere discussie bij TKA, is wat te doen met de patella: resurfacing of niet resurfacing. De aanwezigheid van anterieure kniepijn (AKP) na TKA kan een belangrijke reden zijn voor patiënt ontevredenheid. Zowel voorstanders als tegenstanders van patella resurfacing hebben nog geen overtuigende bewijzen laten zien, wanneer het een of het ander beter is met betrekking tot

het voorkomen van AKP, en bij welk type patiënt. Daarom hebben sommige chirurgen de voorkeur om een secundaire patellaire resurfacing te doen indien AKP postoperatief aanwezig is, echter zonder de eigenlijke oorzaak van AKP te overwegen. Een andere techniek om AKP te verminderen is met diathermie, waarbij een thermische laesie rond het peripatellaire zachte weefsel wordt aangebracht. Het idee van deze patellaire electrocauterisatie is een denervatie waardoor minder efferente pijn signalen worden waargenomen. We hebben een prospectieve studie uitgevoerd of er een verschil is in pijn gewaarwording, functionele, en complicaties uitkomsten tussen intra-operatieve patellaire diathermie en niet-diathermische cauterisatie bij niet geresurfacede patellae tijdens een gelijktijdige bilaterale TKA (**hoofdstuk 4**). 73 patiënten (146 knieën) werden opgenomen in deze studie. De TKA werd uitgevoerd door een enkele ervaren chirurg met behulp van kruisband sparende knieprothese met een vast lager. Circumferentiële patellaire cauterisatie en osteofyt verwijdering werd uitgevoerd van de rechterknie ongeacht de ernst van de artrose. De linker patella werd alleen behandeld met osteophyten excisie zonder cauterisatie. Evaluaties werden gedaan gedurende minimaal 2 jaar follow-up door het beoordelen van ROM, VAS, KOOS Score, Oxford knie Score (OKS), Kujala anterieure kniepijn score, en complicatie. Er werden geen verschillen gevonden in klinische preoperatieve kenmerken en radiologische ernst van de artrose (Kellgren-Lawrence-beoordeling) tussen de groepen. Gemiddelde ROM, VAS, KOOS, OKS, en Kujala knie Score waren postoperatief verbeterd in beide groepen. Echter, er waren geen verschillen in pijn gewaarwording, functionele, en complicaties tussen de patellaire cauterisatie en niet-cauterisatie groepen bij deze gelijktijdig uitgevoerde bilaterale TKA patiënten tijdens follow-up.

Een ander discussie punt bij knieprothese chirurgie betreft de chirurgische techniek om een TKA uit te lijnen en het effect daarvan op de uitkomst. Twee methoden van uitlijning worden gebruikt om een neutrale uitlijning van een knieprothese te krijgen: de anatomische en de mechanische knie uitlijning. Welke superieur is, is klinisch niet duidelijk, maar de meerderheid van de chirurgen gelooft dat de mechanische uitlijning superieur is. Er bestaan echter geen goede studies die bewijst dat de verschil in functionele uitkomsten bestaat tussen anatomische en mechanisch uitlijnen van de knie. Wel is er recent met RSA (microbewegingen van de knieprothese in het bot) aangetoond dat een varus staat (ook bij constitutionele preop varus) meer knieprothese migratie veroorzaakt. De meest recente uitlijningmethode is de kinematische uitlijning. Deze methodiek, claimt dat elke knie individueel uitgelijnd wordt gebaseerd op een pre-artrose situatie, waarbij ook een goede ligamentaire balanceren bereikt wordt. De normale native knie heeft een constitutionele uitlijning, ofwel lichte varus of valgus, binnen 3 graden foutmarges. Met behulp van de kinematische uitlijningsmethode wordt geclaimd dat deze oorspronkelijke uitlijning van de native knie weer bereikt kan worden, zelfs in constitutionele varus of valgus knieën.

Het belang van knieprothese uitlijning is ook van invloed op de precisie van de botresectie dus positie van de knieprothese, die weer invloed heeft op de overleving van de prothese op lange termijn. Ter verbetering van knieprothese uitlijning zijn intraoperatieve instrumenten worden ontwikkeld. Computer-Assisted chirurgische (CAS) navigatie werd hiervoor ontwikkeld, maar met verschillende tekortkomingen (grote, dure apparaten), waarbij ook geen evident voordeel was in vergelijking met conventionele TKA. Hierna werd patiënt-specifieke instrumentatie (PSI) geïntroduceerd, met eveneens geen beter functioneel resultaat in vergelijking met conventionele TKA. Recent werd om de tekortkoming van CAS en PSI te beantwoorden, een op een accelerometer gebaseerde compacte navigatie geïntroduceerd. Het is een compact (past in hand) navigatie apparaat, voor eenmalig gebruik. Dit gesteriliseerde apparaat wordt gebruikt in het operatie, eerst wordt het rotatie centrum van de heup bepaald, waarna de mechanische femorale as wordt bepaald. Het apparaat begeleidt de botresectie in de juiste coronale en sagittale vlakken en valideert de knie as uitlijning en bevestigt de plaatsing van de femorale en tibiale component. Er werd een systematische review van deze op een accelerometer gebaseerde navigatie uitgevoerd in vergelijking met een conventionele TKA (**hoofdstuk 5**). Uiteindelijk werden vier gerandomiseerde studies geïnccludeerd met redelijke tot goede kwaliteit en zes niet-gerandomiseerde studies. De studies lieten tegenstrijdige uitkomsten zien van op accelerometer gebaseerde navigatie in het verminderen van malalignement van implantaten bovendien was er geen verbetering van de door de patiënt gemelde uitkomsten en ook geen vermindering van complicaties. We raden aan om het gebruik van op accelerometer gebaseerde navigatie niet op grote schaal toe te passen voordat er voldoende bewezen voordelen zijn in goed uitgevoerde studies.

Uiteindelijk is er dus zelfs met de nieuwste chirurgische techniek geen evidente functionele verbetering in vergelijking met conventionele TKA. Maar de belangrijkste vraag met betrekking tot uitlijning in TKA is: wat is de beste uitlijning, anatomische uitlijning, mechanische of kinematische uitlijning? Hoeveel mag de knie en dus een uitlijning afwijking van "neutraal" en wat is "neutraal" en wat is aanvaardbaar qua afwijking aan de weke delen rond de knie, voordat er klachten ontstaan?

Ten slotte werden belangrijke postoperatieve complicatie in TKA onderzocht. Veel factoren beïnvloeden het voorkomen van complicaties. Body Mass Index (BMI), leeftijd en een bilaterale knieprocedure in één chirurgische sessie verhogen de incidentie van complicaties. De betreffende afkapwaarden, waarboven meer kans op complicaties optreedt zijn: BMI >30,0 kg/m², leeftijd > 80 jaar, en bilaterale procedure in één sessie waren significante risicofactoren. Veneuze trombo-embolie, diepe veneuze trombose (DVT) en longembolie, behoort tot de op 3 van cardiovasculaire ziekten en treedt op bij 1-2 per 1000 personen in de algemene bevolking. Van deze patiënten heeft 2/3 een DVT en 1/3 een longembolie. De mortaliteit is 12% in 1 jaar. Na een DVT ontwikkelt 50% van de patiënten een post trombotisch syndroom. Om dit risico op DVT te

minimaliseren, is trombose profylaxe belangrijk TKA chirurgie. Alleen hebben niet alle patiënten het nodig, maar onderzoek naar welke groep een hoog risico heeft en dus trombose profylaxe is niet bekend. Momenteel vindt risicostratificatie onderzoek plaats, om zodoende in de toekomst maatwerk, patiënt specifieke, profylaxe te kunnen geven. Een multimodale aanpak, met behulp van chemische en mechanische profylaxe met vroege postoperatieve mobilisatie, is essentieel bij VTE-profylaxe (**hoofdstuk 6**). Chemoprophylaxis middelen die worden gebruikt bij VTE profylaxe zijn aspirine, warfarine, LMWH, fondaparinux, dabigatran, rivaroxaban en apixaban. De sleutel tot het bepalen van de juiste chemoprophylaxe medicamenten is een veilig evenwicht creëren tussen de werkzaamheid van trombose preventie en het vermijden van het risico op bloedingen complicaties. Dit eventueel in combinatie met mechanische onderbeen compressie profylaxe bij specifieke patiënten, kortom maatwerk bij hoog risico patiënten.

Toekomstig onderzoek naar uitkomsten van knieprothese chirurgie zal zich onder andere richten op het preoperatief kunnen voorspellen welke patiënt veel nut zal hebben van een bepaald type interventie, zoals conservatief, osteotomie, unicondylaire, totale knieprothese. Omdat het uiteindelijke doel is tevredenheid van de patiënt bij deze electieve operaties. Hierbij moeten patiënt factoren (i.e. co morbiditeit, verwachting etc.), chirurgische factoren (i.e. knie as, stabiliteit, infectiekans etc.) en postoperatieve revalidatie (i.e. postoperatieve pijn minimaliseren, revalidatie verbeteren, complicaties) geoptimaliseerd worden.

Deze studies moeten gedaan worden op basis van de Indonesische bevolking, waarbij data uit een Implants Register in Indonesië, een belangrijke bijdrage kan leveren aan de kwaliteit van zorg verbetering voor de patiënt door de orthopedisch chirurg. Uiteindelijk is er geen chirurgische innovatie mogelijk zonder evaluatie, dit is de enige voorwaarde die zal leiden tot een verbeterde uitkomst voor onze patiënten.



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Chapter 9

Kesimpulan

Pergantian sendi lutut total (*total knee arthroplasty*, TKA) adalah operasi yang sering dilakukan pada osteoarthritis (OA) lutut tahap lanjut yang menghambat fungsionalitas pasien. Meskipun jumlah TKA semakin meningkat, tingkat ketidakpuasan pasien masih sekitar 20-25%. Ada beberapa alasan yang dapat menyebabkan hal tersebut seperti desain implan, teknik operasi, pemilihan pasien, dan persepsi pasien (latar belakang budaya, ekspektasi terhadap hasil). Untuk meningkatkan kepuasan pasien, diperlukan peningkatan pada kemampuan operasi, pengambilan keputusan mengenai pasien mana yang membutuhkan operasi, dan hal-hal yang perlu dipertimbangkan di dalam TKA, khususnya pada perbedaan luaran pada pasien Asia.

Kepuasan pasien pasca TKA dipengaruhi oleh faktor pasien, teknik operasi, dan komplikasi pascaoperasi. Perencanaan praoperasi, teknik operasi, dan pemilihan implan juga berperan penting dalam kepuasan pasien. Implan yang sesuai dengan bentuk tulang dan tidak *overhang* akan meningkatkan kesintasan implan dan kepuasan pasien. Oleh karena itu, antropometri lutut dan hubungannya dengan ukuran implan sangatlah penting. Studi retrospektif dilakukan untuk menilai perbedaan ukuran antropometri antara pasien-pasien TKA Asia-Indonesia dan Kaukasoid-Belanda dan dibandingkan dengan ukuran sembilan sistem TKA yang berbeda (Vanguard, Genesis II, Persona – *standard* dan *narrow*, GK Sphere, Gemini, Attune – *standard* dan *narrow*, dan Sigma PFC) (**Bab 2**). Data antropometri radiografi pada femur distal, tibia proksimal, dan patela diperoleh dari 67 pasien Kaukasoid dan 67 pasien Asia yang disamakan usia dan jenis kelaminnya. Pada dimensi antero-posterior (AP) dan medio-lateral (ML), ukuran femur dan tibia pasien Kaukasoid lebih besar daripada Asia, tetapi aspek perbandingan (ML/AP) pasien Asia lebih besar daripada Kaukasoid baik pada tibia maupun femur. Pasien Asia relatif memiliki *patella baja* bila dibandingkan dengan Kaukasoid. Secara keseluruhan, ukuran terkecil pada pasien Asia tidak cocok dengan kesembilan sistem TKA. Untuk mencapai implan lutut yang optimal, harus disediakan ukuran implan lutut yang lebih beragam (yaitu ukuran yang lebih kecil). Selain itu, penyesuaian pun harus dilakukan pada TKA untuk mendapatkan implan yang sesuai dengan lutut alamiah. *Overhang* pada implan akan meningkatkan volume dan menekan tendon popliteus, yang akan menyebabkan nyeri menetap pascaoperasi dan menurunkan tingkat kepuasan pasien. Oleh karena itu, harus dilakukan perencanaan praoperasi (jenis dan ukuran implan) pada TKA. Pengukuran implan pra- dan intraoperatif wajib dilakukan untuk menghindari *overhang* dan menghasilkan implan yang sesuai dengan tulang. Pada saat akan dilakukan TKA, persepsi dan ekspektasi pasien pascaoperasi perlu dikontrol dan dioptimalkan walaupun hal itu bersifat subjektif. Latar belakang budaya pasien dapat mempengaruhi persepsi dan ekspektasi terhadap hasil operasi TKA. Perbedaan budaya antar benua juga dapat memengaruhi perbedaan hasil intervensi. Untuk itu, kami melakukan sebuah studi perbandingan antara populasi Asia dan Amerika Utara (**Bab 3**). Studi kohort retrospektif dilakukan untuk membandingkan

76 pasien Asia dan 64 pasien Amerika Utara yang menjalani operasi pergantian sendi lutut total. Data demografis, skor luaran pasien (KSS, PAQ, WOMAC), rentang gerakan lutut (ROM), dan posisi komponen secara radiografi dibandingkan dalam studi ini. Grup pasien Asia memiliki ROM, skor fungsi KSS, dan nyeri PAQ praoperasi yang lebih buruk dibandingkan dengan grup Amerika Utara, tetapi skor KSS dan WOMAC praoperasi sebanding antara kedua grup. Pascaoperasi, skor KSS dan WOMAC pada grup Asia lebih baik bila dibandingkan dengan grup Amerika Utara, sedangkan skor PAQ dan fungsi KSS sebanding antara kedua grup. Meskipun pasien Asia memiliki skor praoperasi yang lebih buruk, hasil pascaoperasi sebanding dengan pasien Amerika Utara. Defisit fungsi dan tingkat nyeri praoperasi yang lebih tinggi pada populasi Asia dapat disebabkan oleh perbedaan budaya dan/atau faktor sosioekonomi. Alasan sosioekonomi inilah yang mungkin menjadi alasan mengapa pasien Asia memiliki kondisi yang lebih buruk pada saat datang untuk konsultasi praoperasi dibandingkan dengan pasien di Amerika Utara. Studi lebih lanjut diperlukan untuk meneliti dampak perbedaan budaya ini terhadap hasil akhir TKA, dimana bahkan dalam satu negara pun ditemukan perbedaan ini, terlebih lagi antar benua.

Selain faktor-faktor pasien, teknik operasi juga memegang peranan penting. Semua ahli bedah diharuskan untuk meningkatkan teknik bedah mereka. Teknik bedah klasik (teknik *gap balancing* dan *measured resection*) telah banyak digunakan. Teknik lain, yaitu teknik *hybrid* (kombinasi teknik *gap balancing* dan *measured resection*) juga sering digunakan. Namun, tidak ada satu teknik pun yang lebih unggul daripada teknik lain dan hal ini masih menjadi perdebatan. Perdebatan lain yang juga muncul adalah apakah perlu untuk meresurfasi patela atau tidak. Nyeri lutut anterior pasca TKA merupakan salah satu faktor penting penyebab ketidakpuasan pasien. Pro dan kontra pun muncul mengenai perlu atau tidaknya meresurfasi patela. Pendukung prosedur ini menyatakan bahwa nyeri lutut anterior akan berkurang dengan meresurfasi patela, tetapi penentang prosedur ini dapat menunjukkan tidak ada perbedaan insidensi nyeri lutut anterior dengan atau tanpa resurfasi patela. Beberapa ahli memilih untuk melakukan resurfasi patela sekunder, pada patela yang tidak diresurfasi untuk mengobati nyeri lutut anterior pascaoperasi tanpa mempertimbangkan penyebab nyeri lutut anterior itu sendiri. Teknik lain yang dapat dilakukan sebagai upaya mengurangi nyeri lutut anterior adalah denervasi patela, yaitu dengan memberikan lesi termal pada jaringan lunak peripatela. Kauterisasi peripatela tersebut dipercaya dapat mengurangi sinyal eferen dari jaringan peripatela, sehingga dapat mengurangi gejala nyeri lutut anterior. Secara teoretis, hal ini seharusnya mengurangi nyeri lutut anterior, tetapi teori ini harus dibuktikan secara klinis. Oleh karena itu, kami melakukan studi prospektif untuk menilai apakah ada perbedaan nyeri, fungsi, dan komplikasi antara patela yang dikauterisasi dan tidak pada TKA bilateral simultan tanpa resurfasi (**Bab 4**). Tujuh puluh tiga pasien (146 lutut) diikutsertakan dalam studi ini untuk menjalani TKA yang dilakukan oleh satu orang

ahli bedah berpengalaman, menggunakan prosthesis *cruciate retaining* dan *insert fixed bearing*. Kauterisasi sirkumferensial hanya dilakukan pada lutut kanan dengan segala tingkat keparahan arthritis yang ada, sedangkan pada lutut kiri dilakukan *debridement* dan eksisi osteofit tanpa kauterisasi. Evaluasi dengan rentang waktu minimal 2 tahun dilakukan dengan menilai ROM, VAS, skor KOOS, skor lutut Oxford (OKS), skor nyeri lutut anterior Kujala, dan komplikasi. Dari studi ini, didapatkan tidak ada perbedaan karakteristik klinis praoperasi dan tingkat keparahan radiologis (skor Kellgren-Lawrence) antar kedua grup. Rerata ROM, VAS, KOOS, OKS, dan skor Kujala membaik pascaoperasi pada kedua grup. Namun, tidak ditemukan perbedaan nyeri lutut, fungsi, dan komplikasi antara patela yang dikauterisasi dan tidak dikauterisasi pada TKA bilateral simultan tanpa resurfasi selama evaluasi minimum 2 tahun.

Alignment pada TKA dan pengaruhnya terhadap hasil masih menjadi perdebatan. Dua metode yang digunakan dalam TKA untuk mencapai *alignment* yang netral adalah: *alignment* anatomis dan mekanis. Tidak ada yang lebih unggul antara satu sama lain, tetapi banyak ahli bedah yang meyakini bahwa *alignment* mekanis lebih unggul. Hasil studi menunjukkan tidak ada perbedaan fungsi antara *alignment* anatomis dan mekanis. Namun, penelitian dengan RSA (gerakan mikro dari prosthesis lutut di tulang) menunjukkan bahwa kondisi lutut yang varus (dan juga varus konstitusional praoperasi) menyebabkan migrasi prosthesis lutut yang lebih banyak. Metode *alignment* terkini yang dipergunakan adalah *alignment* kinematis. *Alignment* kinematis bertujuan untuk mengembalikan *alignment* alami seperti pra-arthritis dan juga keseimbangan ligamen yang baik yang berbeda antar individu. Sendi lutut yang normal memiliki *alignment* konstitusional, baik varus ataupun valgus, sebanyak kurang lebih 3 derajat. Penggunaan *alignment* kinematis akan memungkinkan kita untuk mencapai *alignment* sendi yang alamiah, baik varus atau valgus konstitusional.

Alignment prosthesis juga dipengaruhi oleh ketepatan reseksi tulang dalam teknik *alignment* manapun yang digunakan. Untuk memperbaiki *alignment* lutut dan prosthesis, dikembangkanlah beberapa instrumen intraoperatif. Navigasi operasi berbasis komputer (computer-assisted surgery, CAS) dikembangkan untuk mencapai hal tersebut, tetapi studi menunjukkan beberapa kekurangan (alat yang besar dan mahal) dan tidak ada perbedaan pada fungsi pascaoperasi dibandingkan dengan TKA konvensional. Oleh karena itu, instrumentasi yang spesifik pada pasien (patient-specific implant, PSI) diperkenalkan. Akan tetapi PSI juga tidak memberikan perbedaan fungsi pascaoperasi dibandingkan dengan TKA konvensional. Untuk menjawab kekurangan CAS dan PSI inilah, kemudian diperkenalkan navigasi berbasis akselerometer. Alat ini berupa navigasi yang dapat digenggam, sekali pakai dan steril, yang digunakan pada lapangan operasi untuk menentukan pusat rotasi sendi panggul dan sumbu mekanis femur. Alat ini memandu reseksi tulang pada bidang sagital dan koronal sesuai yang diinginkan, serta memastikan ketepatan *alignment* dan kedudukan komponen

femur dan tibia. Kami melakukan kajian sistematis untuk membandingkan navigasi berbasis akselerometer dengan TKA konvensional (**Bab 5**). Kajian tersebut mencakup empat uji klinis terandomisasi dengan kualitas sedang dan baik, dan 6 studi tanpa randomisasi dengan kualitas sedang dan baik diikutsertakan dalam penelitian ini. Kami menemukan hasil yang bertentangan pada navigasi berbasis akselerometer dalam mengurangi *outliers* implan dan *alignment*, dan tidak ada perbedaan luaran pasien dan komplikasi dengan TKA konvensional. Kami merekomendasikan untuk tidak mengadopsi penggunaan navigasi berbasis akselerometer secara luas sampai terbukti sebaliknya. Bahkan dengan teknik bedah terbaru sekalipun, tidak ada perbedaan fungsi pascaoperasi antara navigasi berbasis akselerometer dengan TKA konvensional. Namun, yang menjadi sebuah pertanyaan besar adalah *alignment* manakah yang terbaik dalam TKA: *alignment* anatomis, mekanis, atau kinematis? Seberapa besar derajat deviasi yang masih dapat diterima dan bagaimana cara mengevaluasi keseimbangan jaringan lunak pada TKA?

Pada akhirnya, banyak faktor yang memengaruhi terjadinya komplikasi pasca TKA yang harus ditangani. Indeks massa tubuh (IMT), usia, dan prosedur bilateral dapat meningkatkan insidensi komplikasi. $IMT \geq 30.0 \text{ kg/m}^2$, usia ≥ 80 tahun, dan prosedur bilateral adalah faktor risiko yang signifikan untuk terjadinya komplikasi sistemik, sedangkan $IMT \geq 30.0 \text{ kg/m}^2$ adalah faktor risiko untuk trombotik vena dalam (*deep vein thrombosis*, DVT) pascaoperasi. Tromboembolisme vena (*venous thromboembolism*, VTE), yaitu DVT atau emboli paru (*pulmonary embolism*, PE), merupakan penyakit kardiovaskular ketiga terbanyak dan terjadi pada 1-2 per 1000 orang per tahun dalam populasi umum. Dari semua pasien penderita VTE, sekitar duapertiga didiagnosis dengan DVT dan sepertiga dengan PE. Untuk meminimalkan risiko ini, profilaksis VTE merupakan suatu keharusan pada TKA, meskipun kita tidak mengetahui secara pasti pasien mana yang membutuhkan profilaksis jangka panjang. Pendekatan multimodal, menggunakan profilaksis kimiawi dan mekanis dengan mobilisasi segera pascaoperasi, sangatlah penting dalam mencegah VTE (**Bab 6**). Agen kemoprofilaksis yang digunakan untuk profilaksis VTE adalah aspirin, warfarin, LWMH, fondaparinux, dabigatran, rivaroxaban, dan apixaban. Kunci dalam menentukan agen kemoprofilaksis yang sesuai adalah mempertimbangkan keseimbangan antara efektivitas obat dengan risiko perdarahan dan mengkombinasikan dengan profilaksis mekanis pada setiap individu. Penelitian ke depan harus berfokus pada bagaimana meningkatkan kepuasan pasien dengan cara mengoptimalkan faktor pasien, meningkatkan faktor bedah (bagaimana cara mengevaluasi keseimbangan jaringan menggunakan peralatan intraoperatif dan cara memperbaiki *alignment* komponen), atau mengoptimalkan perawatan pascaoperasi (meminimalkan nyeri pascaoperasi, memperbaiki rehabilitasi, dan meminimalkan komplikasi pascaoperasi). Studi-studi ini harus didasarkan pada populasi Indonesia dari

Registrasi Implan di Indonesia sendiri. Pada akhir kata, “tidak ada inovasi tanpa evaluasi” merupakan satu-satunya cara untuk meningkatkan luaran untuk pasien kita.



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Appendices

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Linda Rachmat, thank you for being so patient with me all the time we spent in the OR during my doctoral program.

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My appreciation to all my brothers and sisters at Indonesian Hip and Knee Society (IHKS), thank you for being there.

Margaret Salim and Astrid. Both of you are my motivator who tirelessly lift me up so I could reach where I am today.

Finally, my wife dear Ria, my sons Nicolaas Bryant and Nicolaas Edrick, thank you for your eternal accompaniment, support, encouragement, and understanding throughout the years. To my daughter in law, Stephanie and my grandson, Nicolaas Michael, you are the brightest star of my life.

To all my sisters, Astrid and Reggie and their families, no words are enough to convey my gratitude for always supporting me.

Last but not least, to the most important person in my life, my mother, Pretty. You are the precious guiding light for all times. Thank you for all your prayers and encouragements since I was young. To my late father, Nicolaas Aloysius, who was renowned for his generosity. Although you are no longer with us, your spirit are always in our hearts and watch over us.

CURRICULUM VITAE

Nicolaas Cyrillus Budhiparama was born in Medan, Indonesia on February 9th 1961. He earned his medical doctor degree from University of North Sumatera in 1986. He began his training to be an orthopedic surgeon in Leiden in October 1987 under Prof. Dr. P. M. Rozing. Subsequently, he trained as a general surgeon in Westeinde ZH in Den Haag under the late Dr. Bob Koumans. In 1989, he returned to Leiden until he finished his training in 1993. After graduation, he worked as a full staff member and temporarily took the place of chef de clinique.

In 1994, he was asked to work in Indonesia and initiated the collaboration between University of Indonesia and University of Leiden in 1996. His interest in performing adult reconstructive surgery led to several fellowships in Europe and USA.

During his career, he has organized a lot of world class meetings, invited to speak at both National and International forums and appointed to be the board of directors and committees of several elite world organizations. He has founded several organizations, serves as Founding Godfather for Global Campaigns and Presidents for various orthopedic societies. Regarding his concern for promoting education and advancing research, he has founded Nicolaas Institute of Constructive Orthopedic Research and Education Foundation for Arthroplasty and Sports Medicine. His charitable foundation has funded the Paolo Aglietti Award and The Knee Travelling Fellowship at ISAKOS. He has multiple international research collaborations and publications to date.

In 2020, he will be the President of 3 Asia Pacific orthopaedic societies concurrently, namely Asia Pacific Arthroplasty Society (APAS), Asia Pacific Knee Society (APKS), and Arthroplasty Society in Asia (ASIA).

PORTFOLIO

1. Fellowships

- Stanford Fellowship for Arthroplasty, Palo Alto (USA) under Prof. William J. Maloney
- Cotrel Fellowship, Paris (France), under Prof. Dubousset and Dr. Chopin
- AFOR Fellowship, Germany and Switzerland, under Prof. Mittelmeier and Prof. Trentz
- St. Vincent's Hospital, Melbourne (Australia), under Prof. Peter F. Choong

2. Visiting Fellowships

- Harvard Medical School, Boston, (USA) under Prof. Richard Scott and Prof. Thomas S. Thornhill
- Lennox Hill Hospital, New York (USA), under Prof. Chitranjan. S. Ranawat
- Colorado Joint Replacement, Denver (USA), under Prof. Douglas A. Dennis

3. Current Positions

- Founder & Chairman of Nicolaas Institute of Constructive Orthopaedic Research & Education Foundation for Arthroplasty & Sports Medicine
- 1 of 18 Founding Godfathers of ISAKOS Global Connection Campaign
- Founding Chairman and Past President of IHKS (Indonesian Hip and Knee Society)
- Founding Chairman and Past President of AAA (ASEAN Arthroplasty Association)
- President for APKS (Asia Pacific Knee Society) 2019 - 2021
- President for ASIA (Arthroplasty Society in Asia) 2019 – 2020
- President Elect for APAS (Asia Pacific Arthroplasty Society) 2018 – 2020
- Past President of PEROSI (Indonesian Osteoporosis Association) 2014 - 2017
- Declarator of Beijing Declaration at International Presidents' Forum to establish a World Orthopaedic Alliance (WOA)
- Board of Directors for ISAKOS (International Society of Arthroscopy, Knee Surgery & Orthopaedic Sports Medicine)
- Consultant for Executive Committee for ISAKOS
- Deputy Chair of Strategic Planning Committee for ISAKOS
- Chairman of Development Committee for ISAKOS
- Board of Program Committee for ISAKOS
- Board of Scientific Committee for WAIOT (World Association against Infection in Orthopaedics and Traumatology)
- Board of Committee of APOA (Asia Pacific Orthopaedic Association)
- Board of Committee of APKS (Asia Pacific Knee Society)
- Board of Committee of APAS (Asia Pacific Arthroplasty Society)
- Country Representative for APHS (Asia Pacific Hip Society)
- Expert Council for IOA (Indonesian Orthopaedic Association)
- Expert Council for PRSI (Indonesian Swimming Federation)
- Board of Congress Program Committee for APKASS (Asia Pacific Knee, Arthroscopy & Sports Medicine Society)
- Board of Committee of EFORT Asia (European Federation of National Associations of Orthopaedic and Traumatology)
- Global Chair for ICJR (International Congress for Joint Reconstruction)
- Committee member of ICHOM (International Consortium for Health Outcomes Measurement) Hip & Knee Osteoarthritis Working Group
- Regional representative at International Periprosthetic Joint Infection Consensus Meeting - 2018
- Honorable advisor for ASSA (ASEAN Society for Sports Medicine & Arthroscopy)
- Scientific Committee Director of Arthroplasty Society in Asia (ASIA)
- Head of Department of Orthopaedic Surgery at Medistra Hospital, Jakarta – Indonesia

4. Academic Posts

- Ass. Professor at Department of Orthopaedic at Leiden University Medical Center, The Netherlands
- Visiting Professor at Medical School of Chinese People's Liberation Army, Beijing – China
- Faculty for ICJR (International Congress for Joint Reconstruction)
- Global Faculty for AO Reconstruction
- Senior Lecturer for School of Medicine of University of Gajah Mada, Jogjakarta – Indonesia
- Senior Lecturer for School of Medicine of University of Airlangga, Surabaya - Indonesia
- Senior Lecturer for School of Medicine of University of Pelita Harapan, Jakarta - Indonesia
- Chairman of Committee for National & Foreign Affairs for Indonesian Collegium of Orthopaedic & Traumatology
- Chairman/PIC for Collaboration between Indonesia Collegium of Orthopaedic & Traumatology and Australian Orthopaedic Association
- Examiner for Indonesian National Orthopaedic Board Exams for Indonesian Collegium of Orthopaedic & Traumatology
- Fellowship Committee and Instructor for Indonesian Hip & Knee Society Fellowship Program

5. Editorial Posts

- Associate Editor in Chief for Arthroplasty – official journal for ASIA
- Associate Editor for AJO (The American Journal of Orthopedics)
- Editorial Board Representative for OJSM (Orthopaedic Journal of Sports Medicine) – open access journal by AOSSM (American Orthopaedic Society for Sports Medicine)
- Editorial Board for International Journal of Musculoskeletal Infection
- Editorial Board for CIOS (Clinics In Orthopaedic Surgery)
- Corresponding Editor for JOS (Journal for Orthopaedic Surgery)
- Editorial Board for Arthropaedia
- Reviewer for CORR (Clinical Orthopaedic and Related Research)
- Reviewer for JOA (Journal of Arthroplasty)
- Reviewer for AJSM (American Journal of Sports Medicine)
- Reviewer for KSSTA (Knee Surgery, Sports Traumatology & Arthroscopy) – official journal for ESSKA (European Society of Sports Traumatology Knee Surgery and Arthroscopy)
- Reviewer for JISAKOS (Journal of ISAKOS)
- Reviewer for Knee journal

- Member of ASBMR (American Society of Bone Mineral & Research) International Task Force to address “Systems Approaches to Osteoporotic Fracture Secondary Prevention”
- Editor of ASEAN Arthroplasty Association (AAA) Comprehensive Hip & Knee Textbook 1st Edition

6. Presentations

2019

Keynote Speaker and moderator

- o Launch of Arthroplasty Journal. The 12th Congress of Chinese Association of Orthopaedic Surgeons (CAOS), Beijing, China
- o Knee Arthroplasty. The 7th ICJR, Dubai, United Arab Emirates
- o Return to Sports Post Injury for World Class Athletes. The 67th COE of IOA, Solo, Indonesia
- o The 12th Congress of Chinese Association of Orthopaedic Surgeons, Beijing, China
 - New Technology: Is the Latest Always The Greatest?
 - Periprosthetic Fractures of the Lower Extremities: Global Trends & Challenges
- o Total Knee Arthroplasty at 11th JOSKAS Congress in Sapporo, Japan
- o Total Knee Arthroplasty in Principles of Total Hip & Knee Arthroplasty at AO Recon course, in Jakarta, Indonesia
- o Combined 6th IHKS – 11th APKS - APIS Meeting in Yogyakarta, Indonesia
 - New Technology in TKR: Is The Latest Always The Greatest?
 - Management of Acute PJI, DAIR or Not?
 - How Does The Modern Knee Design Improve Patient Outcomes?
 - Controversial Issues Discussions on Arthroplasty
 - PJI Session
 - Meet The Experts in Arthroplasty
- o Primary TKA: Why do They Go Wrong? 20th APAS Meeting in Xiamen, China
- o New Technology in TKR: Is The Latest Always The Greatest. The 41st Australian Knee Society Meeting, Canberra, Australia
- o New Technology in TKR: Is The Latest Always The Greatest? The 7th ASIA Meeting & AO Recon Seminar, South Korea

Invited speaker

- o Comparing the Outcome of Circumferential Patellar Denervation in Unresurfaced Simultaneous Bilateral Total Knee Arthroplasty. The 7th European Knee Society Closed Meeting, Megeve, France

- o The 7th ICJR ME Dubai, United Arab Emirates
 - Comparing the Outcome of Circumferential Patellar Denervation in Unresurfaced Simultaneous Bilateral TKA
 - The Real Value of DAIR: What does the 2018 consensus say?
- o The 12th ISAKOS Congress, Cancun, Mexico
 - Target for Appropriate Alignment
 - The Role of New Technologies
 - DAIR: What does the 2018 consensus say?
 - Extensor Mechanism Rupture?
- o Limb Alignment & Kinematics. AO Recon course, Jakarta, Indonesia
- o Return to Sports After Knee Injury for World Class Athlete. University of Sumatra Utara 67th Anniversary, Medan, Indonesia
- o The 20th APAS Meeting, Xiamen, China
 - Comparing the Outcome of Circumferential Patella Denervation in Unresurfaced Simultaneous Bilateral TKA
 - Does Accelerometer-Based Navigation have any Clinical Benefit compared to Conventional TKA?
- o The 79th AOA ASM Meeting, Canberra, Australia
 - New Technology in TKR: Is The Latest Always The Greatest
 - He Who DAIRS Wins
- o Comparing the Outcome of Circumferential Patella Denervation in Unresurfaced Simultaneous Bilateral TKA. The 41st Australian Knee Society Meeting, Canberra, Australia
- o Navigated Assisted TKA: The Specific Indications. The 20th ASIA Meeting & AO Recon Seminar, South Korea

Instructor

- o IHKS Fellowship Training, Surabaya, Indonesia
 - Basic Total Knee Arthroplasty
 - Tribological and Implant Design
- o Total Hip & Knee Arthroplasty. Principles of Total Hip and Knee Arthroplasty. AO Recon, Jakarta, Indonesia.

Panelist

- o Challenging Case – Total Knee Arthroplasty. The 7th ICJR, Dubai, United Arab Emirates
- o Hip Panel Discussion: Meeting The Experts. The 20th APAS, Xiamen, China
- o VOC on Robotics by DePuy J&J, Singapore

2018

Course chairman/director

- o The 20th Asia Pacific Orthopedic Association Congress, Antalya, Turkey

Keynote Speaker and moderator

- o Hip Arthroplasty. The 6th ICJR ME, Dubai, United Arab Emirates
- o Hip Arthroplasty. The 2nd World Arthroplasty Congress, Rome, Italy
- o Revision and Complications of Knee Replacement. The 78th AOA & APKASS Meeting, Sydney, Australia

Invited speaker

- o The 6th ICJR ME, Dubai, United Arab Emirates
 - Early Revision of PJI: What is The Real Value of DAIR?
 - Periprosthetic Fracture around the Knee: Is Arthroplasty an Option?
 - Effective Methods to Prevent Hip Dislocation
- o The 20th Asia Pacific Orthopedic Association Congress, Antalya, Turkey
 - Periprosthetic Fractures around Tibial Component of TKR
 - The Real Value or Early Revision: DAIR – Indications and Limitations
 - Measured Resection & Manual Release
- o Current Updates in Computer Navigation for TKA. The 2nd World Arthroplasty Congress, Rome, Italy
- o The 6th Annual Meeting of Emirates International Orthopedic Congress, Dubai, UAE
 - Gap Balance vs Measured Resection Technique
 - The Real Value of Early Revision: DAIR – Indications & Limitations
- o The 78th AOA & APKASS Meeting 2018 in Sydney, Australia
 - Should we resurface the patella in TKR?
 - Management of periprosthetic infection: the role of DAIR
- o AO Recon, Singapore
 - Extensor Mechanism failure and patellofemoral complications
 - Periprosthetic fractures around the knee
- o The 2nd Consensus Meeting 2018 on PJI, Philadelphia, USA
 - Is Undergoing a colonoscopy or upper GI endoscopy after Total Joint Arthroplasty associated with an increased risk of SSI/PJI? If yes, does antibiotic prophylaxis prior to a colonoscopy or upper GI endoscopy after Total Joint Arthroplasty reduce the risk of SSI/PJI?
 - Can Debridement, Antibiotics, and Implant Retention (DAIR) be Utilized in the Treatment of Acute PJI with a Megaprosthesis?
 - What is the Definition of PJI of the Knee and the Hip? Can the Same Criteria Be Used for Both Joints?

- o The 19th APAS, Bangkok, Thailand
 - Early Revision of PJI Revision: What is the Real Value or DAIR?
 - Does New Technology in TKA Improve Patient's Outcome?
- o The 18th Journées Lyonnaises de Chirurgie du Genou, Lyon, France
 - Revision for Periprosthetic Fracture: Specific management of periprosthetic tibial fractures
 - Revision due to Infection: What decision to make for which infection? DAIR: Debridement antibiotic and implant retention
- o How to Make Perfect Femoral Rotation. The 10th APKS Meeting, Gwangju, South Korea
- o The 6th Annual Meeting of Arthroplasty Society in Asia, Shanghai, China
 - Solution for Periprosthetic Fracture
 - Solution for Infected TJA
- o The 10th PEROSI-ISCD Bone Densitometry & Body Composition Course, Jakarta
 - Clinical Management Part 1: Non-Pharmacologic, Estrogen & SERM Treatment
 - Clinical Management Part 2: Pharmacologic Treatment Continued
 - Clinical Management Part 3: Further Pharmacologic Treatment Considerations

Panelist

- o Arthroplasty/Osteoarthritis Forum. The 78th AOA & APKASS Meeting, Sydney, Australia
- o The 19th APAS Meeting, Bangkok, Thailand
 - Early Revision of PJI Revision: What is the Real Value or DAIR?
 - Does New Technology in TKA Improve Patient's Outcome?

2017

Course chairman/director

- o Infection Section. The 20th APOA Trauma & Infection Meeting, Kuala Lumpur, Malaysia
- o ICJR Symposium. Combined 5th IHKS - ICJR Symposium, Jakarta, Indonesia
- o Early Intervention for OA: A World Perspective Round Table Discussion. Combined 5th IHKS - ICJR Symposium, Jakarta, Indonesia
- o Principles of Total Hip & Knee Arthroplasty. AO Recon Course, Jakarta, Indonesia

Keynote speaker and moderator

- o Surgical Demonstration: Tibia First Balanced Femur Total Knee Arthroplasty. The 11th ISAKOS Congress, Shanghai, China
- o Combined 5th IHKS - ICJR Symposium, Jakarta, Indonesia

- The Great Knee Debate: Should We Progress to Kinematic Alignment Rather Than Mechanical Alignment
- The Great Knee Debate: Cementless TKA vs All Poly Tibial Tray
- World Perspective Discussion: THA for Young Adult: Bearing Surface
- Knee Arthroscopy
- o The 1st THKS/AAA Master Course, Chiang Rai, Thailand
 - Revision THA Module 2: Moderate to severe Femoral Bone Loss
 - Revision THA Module 4: Periprosthetic Joint Infection
- o AO Recon Course, Jakarta, Indonesia
 - Performing Total Hip Arthroplasty
 - Optimizing Expectations & Outcomes
- o The 7th PEROSI National Congress, Medan, Indonesia
 - Surgical Management of Osteoporotic Fracture
 - Zoledronic Acid: An Effective Once Yearly Infusion for Osteoporosis Treatment

Invited speaker

- o How I Treat Infected Arthroplasty? The 20th APOA Trauma & Infection Meeting, Kuala Lumpur, Malaysia
- o How to Best Achieve Your Target? CAS. The 7th European Knee Society Closed Meeting, London, UK
- o Measured Resection vs Gap Balancing Technique in TKR: With Specific Reference to Patients' Reported Outcome Measures. APKASS 2017 Meeting, Seoul, South Korea
- o Case Study Review. The 1st ISCD Vertebral Fracture Assessment Course, Jakarta, Indonesia
- o The 11th ISAKOS Congress, Shanghai, China
 - Extensor Mechanism Rupture
 - Early Revision: What is The Real Value? (DAIR – Indications & Limitations)
 - What is the Target for Femoral Component from a Clinical Standpoint?
- o The 19th THKS Meeting, Hua Hin, Thailand
 - Extensor Mechanism Rupture in 2017
 - Early Revision: What is The Real Value? (DAIR – Indications & Limitations)
 - How I Treated Infected Arthroplasty?
- o Periprosthetic Fracture in Lower Extremities in 2017: Global Trends & Challenges. Combined 5th IHKS - ICJR Symposium, Jakarta, Indonesia
- o The 1st THKS/AAA Master Course, Chiang Rai, Thailand
 - Revision THA Module 3: Instability After THA - Effective Methods to Prevent Hip Dislocation
 - Revision TKA Module 3: Painful Unstable TKA - Identify Etiology & Types of Instability After TKA

- o The 7th ISCD Course, Jakarta, Indonesia
 - Clinical Management Part 1: Non-Pharmacologic, Estrogen & SERM Treatment
 - Clinical Management Part 2: Pharmacologic Treatment Continued
 - Clinical Management Part 3: Further Pharmacologic Treatment Considerations
- o AO Recon Course, Jakarta, Indonesia
 - Patellofemoral Resurfacing and Tracking
 - Diagnosis and Treatment of Infection in TKA
- o Penatalaksanaan Terkini OA Lutut & Panggul (Current Management of Hip & Knee Osteoarthritis). IOA Seminar, Aceh, Indonesia

Instructor

- o DePuy J&J: Attune. Combined 5th IHKS - ICJR Symposium, Jakarta, Indonesia

2016

Keynote speaker and moderator

- o TKR and New Technology. The 19th APOA Congress, Melbourne, Australia
- o Patella Resurfacing in all TKAs is a Must. The 17th APAS Meeting, Penang, Malaysia
- o Symposium: Management factors for Success in Primary TKA. The 8th APKS Meeting, Yokohama, Japan
- o The Benefits of Viscosupplementation Injections for Treatment of OA. Meet The Expert, Jakarta, Indonesia

Invited speaker

- o Periprosthetic Tibial Fracture. The 19th APOA Congress, Melbourne, Australia
- o The 2nd Basic Orthopaedic Skill Course, Surabaya, Indonesia
 - How I Do My TKR? Step by Step Techniques
 - Managing Intraoperative Issues and Postoperative Rehabilitation
- o The 3rd ICJR Pan Pacific, Kona, Hawaii
 - Measured Resection vs Gap Balancing Technique for TKR with specific reference to patient reported outcome
 - Is The Definition of High Flexion TKA The Same for Asian & Western Patients?
- o The 18th APAS Meeting, Penang, Malaysia
 - Periprosthetic Tibial Fracture
 - Measured Resection vs Gap Balancing Technique for TKR with specific reference to patient reported outcome
- o A Comparison of Clinical and Patient Recorded Outcomes of TKR in Asian versus Western Patients. The 2nd Combined European Knee Society & American Knee Society Closed Meeting, Paris, France
- o SOA/AO Recon Course, Singapore

- Periprosthetic Fractures of the Lower Extremities: Global Trends & Challenges
- How Do I Manage Insitu Hardware When Converting to a TKA?
- Measured Resection vs Gap Balancing Technique for TKR with specific reference to patient reported outcome
- o Measured Resection vs Gap Balancing Technique in TKR: With Specific Reference to Patients' Reported Outcome Measures. The 8th APKS Meeting, Yokohama, Japan

Instructor

- o Workshop TKA by DePuy Synthes. Basic Orthopaedic Skill Course, Surabaya, Indonesia

Panelist

- o How Do We Minimize Infection? The 3rd ICJR Pan Pacific, Kona, Hawaii
- o Panel Discussion. The 8th APKS Meeting, Yokohama, Japan

2015

Course chairman/director

- o Controversial Issues in Arthroplasty & Worst Case. The 4th IHKS Meeting, Surabaya, Indonesia
- o Knee Symposium. APAS Meeting, Delhi, India

Keynote speaker and moderator

- o The 10th ISAKOS Meeting, Lyon, France
 - Knee: Replacement
 - Total Knee Replacement
- o ASEAN Forum. Combined 7th APKS - 17th THKS - 8th AAA Meeting, Bangkok, Thailand
- o How Can We Optimize Patient Satisfaction After TKA. The 4th IHKS Meeting, Surabaya, Indonesia
- o Osteoporosis and Osteoarthritis. PEROSI Annual Scientific Meeting, Jakarta, Indonesia

Invited speaker

- o Patellar Resurfacing, What Are The World Saying? Inaugural World Arthroplasty Congress by ICJR 2015, Paris, France
- o How to Improve TKR? Patellar Replacement? The Master's Series at USC Keck School of Medicine, Los Angeles, USA
- o Patellofemoral Resurfacing in TKA. Combined 7th APKS - 17th THKS - 8th AAA Combined Meeting, Bangkok, Thailand
- o The 4th IHKS Meeting, Surabaya, Indonesia

- What Are The Causes of Patient Dissatisfaction After TKA?
- Measured Resection vs Gap Balancing Technique for TKR With Specific Reference to Final Outcomes
- Stability in Motion, New Advantage for TKR Surgery (Attune)
- Design Features & Early Experience With a Modern TKA
- Launching of Attune RP Implants in Asia Pacific
- o The 16th APAS Meeting, Delhi, India
 - New Technology in TKA: Is The Latest Always The Greatest?
 - Measured Resection vs Gap Balancing Technique for TKR
 - Patella Resurfacing: What Are The World Saying?
- o The 2nd ICJR SEA Meeting, Penang, Malaysia
 - Resurfacing Patella – Pro vs Against (Against)
 - The Biomechanics and Asymmetric Knees
- o The 6th PEROSI Annual Scientific Meeting, Jakarta, Indonesia
 - Making the First Fracture the Last Fracture: an ASBMR Task Force Report
 - Defining an International Standard Set of Outcomes Measures for Patients with Hip or Knee Osteoarthritis: Consensus of the ICHOM Hip and Knee Osteoarthritis Working Group
- o Knee Injuries: When to Do Surgery & Does it Guarantee Results? Indonesian Olympic Committee (IOC) Sports Medicine Symposium & Course, Jakarta, Indonesia

Instructor

- o Cadaveric Workshop on Arthroplasty. Combined 7th APKS - 17th THKS - 8th AAA Meeting, Bangkok, Thailand

Panelist

- o The Master's Series at USC Keck School of Medicine, Los Angeles, USA:
 - Case Presentations for TKR
 - Stem Cells/PRP Injections in Orthopedics
- o Measured Resection vs Gap Balancing Technique for TKR With Specific Reference to Final Outcomes. The 10th ISAKOS Meeting, Lyon, France
- o Case Discussion – Knee: Primary & Difficult Primary. The 2nd ICJR SEA Meeting, Penang, Malaysia

2014

Keynote speaker and moderator

- o The 12th Ranawat Orthopaedic Center Meeting, New Delhi, India
 - Patella Replacement - Replace or not?
 - Venous Thromboembolism Prevention

- o When to Do a Scope in Degenerate Knee? Panelist - Case Challenges for Total Knee Replacement: Can the Surgeon Get It Right? The Master's Series by USC Keck School of Medicine, Los Angeles, USA
- o The 15th APAS, Cheng Du, China
 - CAS: Dreams or Facts? The Value of Daily Work in TKR
 - Venous Thromboembolism Prevention in Orthopaedic Surgery: Current Practice & Unmet Needs
- o THA Dislocation. The 2nd ICJR (International Congress for Joint Reconstruction) Pan Pacific, Hawaii, USA
- o The 1st ASEAN Insight Meeting, Phuket, Thailand
 - Crossfire: Measured resection or Gap balancing: What is the key to the knee?
 - Crossfire: Femoral/Tibial Stems : Cemented or Cementless? What works best?
- o The 27th ISTA (International Society for Technology in Arthroplasty), Kyoto, Japan
 - Hip Resurfacing, Bone & Joint Preservation
 - Bone & Joint Preservation
 - Hip Revision II
- o The 2nd ASIA Meeting, Seoul, South Korea
 - Quality of Life Following TKR in 3 Distinct Patient Population
 - Revision Total Knee Replacement

Invited speaker

- o Technical Tips for Total Knee Replacement. The Master's Series by USC Keck School of Medicine, Los Angeles, USA
- o The 2nd ICJR Pan Pacific, Hawaii, USA
 - Effective Methods to Prevent THA Dislocation
 - CAS: Dreams or Facts? The Value of Daily Work in TKR
- o Versatility of TKR – Postpone Revision by Doing a Good Primary. ASEAN Insight Meeting, Phuket, Thailand
- o The 27th ISTA, Kyoto, Japan
 - CAS: Dreams or Facts? The Value of Daily Work in TKR
 - The Patella in TKA: To Resurface or Not is The Question
- o The 5th PEROSI Congress, Solo, Indonesia
 - Making the First Fracture the Last: Secondary Fracture Prevention (Read by dr. Kiki Novito)
 - Algorithm of Osteoporosis
 - Osteoarthritis Management at Different Stages of Disease
- o Why Total Knees Fail in 2014? – Pitfalls and Pearls for Successful TKR. IHKS Specialty Day, 14th IOA National Congress, Jakarta, Indonesia
- o Combined 65th POA - 7th AAA - 1st ASSA - AOA Meeting, Cebu, The Philippines

- Patella Resurfacing – Will This Ever End? I Don't
- The New, The Bad & The Ugly Knees
- o Patella Resurfacing: Necessary or Not? What Are The World Saying? ICJR India, Delhi, India
- o The 5th Chandra Knee Foundation Meeting, Ahmedabad, India
 - Why TKAs Fail in 2014?
 - Patella Resurfacing: Necessary or Not? What Are The World Saying?
- o Development of Arthroplasty in Indonesia. The 1st Symposium & Cadaveric Workshop, Bandung, Indonesia

Panelist

- o The Master's Series by USC Keck School of Medicine, Los Angeles, USA
 - One Stage Reimplantation: Indications & Technique
 - Pain Management and Rapid Recovery/Discharge for Total Hip Replacement
 - Obamacare & Your Practice

2013

Keynote speaker and moderator

- o The 3rd IHKS Scientific Meeting, Jakarta, Indonesia
 - The Development and Current Status of Hip & Knee Surgery in Indonesia
 - Managing Hip Fractures and their Sequelae with Arthroplasty
 - Controversial Issues of Hip & Knee Arthroplasty
 - Eliquis Lunch Symposia
 - ASKOT Study: An Evaluation of the Acceptability & Safety in Real Life Conditions of a Viscoelastic Solutions of Hyaluronic Acid in Treatment of Knee Osteoarthritis
 - Proactive Knee Management of Knee OA - A Viscosupplementation Approach
- o Current Approach to Prevent Thromboembolism After Orthopaedic Surgery. The 1st Asia Arthroplasty Thromboprophylaxis Survey Working Group Meeting, Hong Kong.
- o The Patella in Total Knee Arthroplasty. The 15th THKS Meeting, Bangkok, Thailand
- o Proactive Knee Management of Knee OA - A Visco-supplementation Approach. The 4th Indonesian Osteoporosis Association National Scientific Congress, Palembang, Indonesia
- o The Patella in Total Knee Arthroplasty - Necessary or Not? Combined 8th COA Congress - 1st ASIA Meeting in Beijing, China
- o The 2nd EOA International Meeting, Dubai, United Arab Emirates
 - Do We Need to resurface the Patella: What the World is Saying?
 - Introduction to new Technology in TKA: Is the latest always the greatest?
 - CAS: Dreams or facts? The value of daily work in TKA

Instructor

- o Cadaveric Hip & Knee Workshop. The 1st AAA Comprehensive Hip & Knee Course, Bangkok, Thailand

Panelist

- o What is the preferred bearing surface in THA in young active around the world? The 2nd EOA International Meeting, Dubai, United Arab Emirates

2012

Keynote speaker and moderator

- o The 2nd Indonesia Hip & Knee Society Meeting, Jakarta, Indonesia
 - The Development and Current Status of Hip & Knee Surgery in Indonesia
 - Unveil the Facts of COX2 Inhibitor in Orthopaedic Cases Management
 - Arthroplasty Crossfire Debate
 - Thrombosis Management in Orthopaedic Surgery, Do We Need a Paradigm Shift?
- o Principles and Roles of Arthroscopy. The 4th Indonesian Osteoporosis Association Meeting
- o Venous Thromboembolism Prevention (VTEp) in Orthopaedic: Current Practice and Unmet Needs. The 14th APAS Meeting, Mumbai, India
- o Conventional Polyethylene vs Highly Cross-linked Polyethylene in TKR patients. The 1st Meeting of Chinese Japanese Korean (CJK) Meeting, Seoul, South Korea
- o Varus/Valgus Knee. The 2nd IHKS Instructional Course & Cadaveric Workshop on THA and TKA, Malang, Indonesia

Invited speaker

- o Venous Thromboembolism Prevention (VTEp) in Orthopaedic: Current Practice and Unmet Needs. The 1st Asia Expert Panel Meeting for Better VTE Prevention for Orthopaedic Patients, Bali, Indonesia
- o Does DVT Exist in Asia? The 59th COE Meeting in Bandung, Indonesia
- o Venous Thromboembolism Prevention (VTEp) in Orthopaedic: Current Practice and Unmet Needs. The 1st Pacific Rim Orthopaedic Symposium (PROS), Bangkok, Thailand
- o 1st ICJR South East Asia Course, Kuala Lumpur, Malaysia
 - Patellar Resurfacing – Yes or No?
 - Patellar Tendon Ripped Off
- o Varus/Valgus Knee. The 2nd IHKS Instructional Course & Cadaveric Workshop on THA and TKA, Malang, Indonesia
- o Conventional Polyethylene vs Highly Cross-linked Polyethylene in TKR patients. The 35th Singaporean Orthopaedic Association Meeting, Singapore

- o Surgical Aspect of Osteoporosis Therapy. The 12th Indonesian Osteoporosis Association Meeting
- o Venous Thromboembolism Prevention (VTEp) in Orthopaedic Patients in Asia: Current Practice and Unmet Needs. The 7th COA Meeting in Beijing, China
- o The 3rd Chandra Knee Foundation Meeting, Ahmedabad, India
 - Conventional Polyethylene vs Highly Cross-linked Polyethylene in Total Knee Replacement Patients
 - Patella Resurfacing – Necessary or Not?
 - Patient Specific Implants vs Computer Assisted Surgery ~ Patient Specific Implants

2011

Keynote speaker and moderator

- o TKA: Uni, High flex and others. Combined 13th APAS - 6th COA Meeting, Beijing, China
- o What's New with Poly in TKR? Combined 41st MOA - 4th AAA Meeting, Kuala Lumpur, Malaysia

Invited speaker

- o CAS TKA: Is It Still There? Is The Definition of High Flexion The Same for Asian and Western Patients? The 13th THKS Meeting, Hua Hin, Thailand
- o What's New in Poly for TKR? Combined 13th APAS - 6th COA Meeting, Beijing, China

Instructor

- o Balancing Varus/Valgus Deformities. The 1st IHKS Instructional Cadaveric Course, Malang, Indonesia

2010

Keynote speaker and moderator

- o CAS TKA: Is It The Best Choice and My Mid to Long term TKA results in ASEAN Countries? (Indonesia). The 3rd AAA Meeting, Phuket, Thailand
- o MIS & CAS: Dreams or Facts? The Value for Daily Work in TKA. The 12th APAS Meeting, New Delhi, India

Invited speaker

- o MIS & CAS: Dreams or Facts? The Value for Daily Work (Asian Perspective). The 2nd EFORT Meeting, Madrid, Spain
- o CAS TKA: Is It The Best Choice and My Mid to Long term TKA results in ASEAN Countries? (Indonesia). The 3rd AAA Meeting, Phuket, Thailand

- o MIS & CAS: Dreams or Facts? The Value for Daily Work in TKA. The 12th APAS Meeting, New Delhi, India
- o CAS - Dreams or Facts? The Value for Daily Work in TKA. Combined 33rd SOA - 30th AOA Meeting, Singapore
- o Glucosamine & Hyaluronan for Treatment of Knee OA. The 2nd EFORT Asia Meeting, Taipei, Taiwan

2009

Keynote speaker and moderator

- o Combined 60th POA - 25th APOA - 2nd AAA Meeting, Manila, Philippines
 - Current Management of Periprosthetic Fractures.
 - MIS & CAS: Dreams or Facts? The Value for Daily Work (Asian Perspective)

Invited speaker

- o MIS & CAS: Dreams or Facts? – The Value for Daily Work (Asian Perspective). The 1st EFORT ASIA Meeting, Bangkok, Thailand
- o Combined 60th POA - 25th APOA - 2nd AAA Meeting, Manila, Philippines
 - Current Management of Periprosthetic Fractures.
 - MIS & CAS: Dreams or Facts? The Value for Daily Work (Asian Perspective)

