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RESEARCH

Wear patterns of compartments in varus knee osteoarthritis among an asian population: A cross-sectional study with radiographic and intraoperative analysis

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Abstract

Purpose Osteoarthritis (OA) of the knee significantly impairs mobility and quality of life. Knee arthroplasties have dramatically improved patient outcomes, allowing individuals to regain independence. Unicompartmental knee arthroplasty (UKA) is a surgical option for patients with isolated single-compartment disease, offering the benefits of reduced surgical time and minimized surgical risks. However, the appropriateness of UKA is often underestimated. Therefore, this study aims to determine the proportion of patients with varus knee OA who are suitable candidates for UKA.

Methods A prospective cross-sectional study was conducted on 207 knees undergoing knee arthroplasty surgery for varus knee OA. Pre-operative radiographs were graded using both the Kellgren-Lawrence (KL) and modified Keyes classifications. Intra-operatively, the knees were inspected, and photographs of the tibial cut were reviewed by a neutral observer. The appropriateness of UKA was determined based on these evaluations.

Results The lateral compartment was not involved in 169 (81.6%) knees. Only six (2.9%) knees had a KL grade 4 involvement of the lateral compartment. After excluding patients with isolated medial compartment OA, no radiographic evidence of lateral and patellofemoral involvement, and a grade 1 on the modified Keyes classification, we found that 79 (38.2%) patients were suitable candidates for a medial UKA. Intraoperatively, 84 (40.6%) patients had a functional ACL with no observable wear in the lateral and patellofemoral joint (PFJ) compartments.

Conclusion In patients with varus knee OA, a significant proportion have wear patterns suitable for management with a UKA. Identifying these patients requires targeted examinations and specific radiographic views.

Keywords Knee osteoarthritis · Tibial wear · Total knee arthroplasty · Unicompartmental knee arthroplasty

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Introduction

Knee osteoarthritis (OA) is a prevalent condition that significantly impacts mobility and quality of life [1]. Knee arthroplasties have revolutionized disease management, offering substantial symptom relief and restoring premorbid functional state. Total knee arthroplasty (TKA) is a widely performed procedure, and its demand is expected to rise with the aging global population. Partial knee replacement, an alternative for end-stage knee OA, involves replacing only the affected compartments, thereby preserving unaffected compartments and maintaining more natural knee kinematics and motion. Options include medial or lateral unicompartmental knee arthroplasty (UKA) and patellofemoral joint replacement (PFJR). Partial knee replacement offers advantages such as a less invasive approach, lower complication rates, quicker rehabilitation, earlier recovery, and improved range of motion [2, 3].

Arthritic changes predominantly affect the medial tibiofemoral compartment, as this area experiences the greatest load [4]. The Oxford mobile-bearing UKA is a well-established procedure with favourable outcomes, even in younger, more active, and overweight patients [5]. Functional outcomes with UKA often surpass those of total knee arthroplasty (TKA), with patients reporting less awareness of the artificial joint [6, 7]. Although Asia's population is relatively younger compared to Western countries, the elderly population is growing [8]. In the United States, knee replacement prevalence is 2.92% at age sixty and rises to 7.29% at age seventy [9], with higher estimates especially among individuals of Chinese descent [10].

In Asia, UKA is significantly less utilized compared to TKA. Surgeons often express concerns about arthritis progression in non-replaced compartments, a steeper learning curve for UKA, and reports of shorter survivorship, which hinder the adoption of UKA. Although many of these concerns have been rebuffed [11, 12], existing lateral OA preoperatively can lead to transfer arthritis. The frequency of UKA procedures performed by a surgeon is inversely correlated with complication rates [13]. Patellar morphology significantly influences clinical outcomes following UKA, with Wiberg type III patellae associated with increased anterior knee pain and patellar tilt postoperatively [14]. Understanding the proportion of OA patients with suitable disease patterns for UKA can aid surgeons in determining whether to learn and implement UKA techniques for these patients. Additionally, misconceptions about knee arthroplasty in the Asian population [15], often result in patients presenting at more advanced stages of the disease, which renders them unsuitable for UKA.

Hence, we studied consecutive patients undergoing TKA across five hospitals in Klang Valley, involving the urban and suburban regions around Kuala Lumpur, the capital city of Malaysia. Our assessment included preoperative radiographs of the knee and intra-operative findings to evaluate wear patterns of the knees and determine the proportion of patients with varus knee OA suitable for partial knee replacement.

Methods

This study was approved by the Malaysian Research and Ethics Committee (No: NMRR- 19–2960–49653). It involved five public hospitals in the Klang Valley, including Universiti Malaya Medical Centre, Hospital Pengajar University Putra Malaysia, Hospital Klang, Hospital Sungai Buloh, and Hospital Selayang. Written informed consent was obtained from all patients. Patients with varus knee OA scheduled for TKA between June 2019 and May 2021 were recruited prospectively. All participants had failed conservative management and exhibited at least grade 3 Kellgren-Lawrence (KL) changes in at least one knee compartment. Exclusion criteria included: (i) valgus knee deformities, (ii) inflammatory arthritis such as rheumatoid arthritis or ankylosing spondylitis, (iii) prior knee surgeries, and (iv) extra-articular limb malalignments, such as those from previous fractures or skeletal dysplasia.

Radiological examinations

Radiographs were obtained and assessed according to the Oxford Radiological Decision Aid (ORDA), a validated algorithm for assessing suitability for UKA, as illustrated in Fig. 1.

Preoperative imaging included weightbearing anteroposterior (AP) and non-weightbearing lateral radiographs of the affected knee. The weightbearing AP films were taken with the patella facing forward and the knee fully extended, while the lateral films were captured with the patient lying on their side and the knee slightly flexed. Additionally, varus and valgus stress views were performed with the knee in 20 degrees of flexion and the radiographic beam aligned parallel to the joint surface. Lastly, a skyline view was obtained with the knee in 30 degrees of flexion.

Radiological assessment

The radiographs were reviewed to determine the severity of OA. The medial and lateral compartments were individually graded using the Kellgren-Lawrence (KL) classification based on the weight-bearing AP radiographs. The KL grading system is as follows: grade 0 -no osteophytes and no joint space narrowing; grade 1—possible osteophytes only; grade 2—definite osteophytes with probable joint

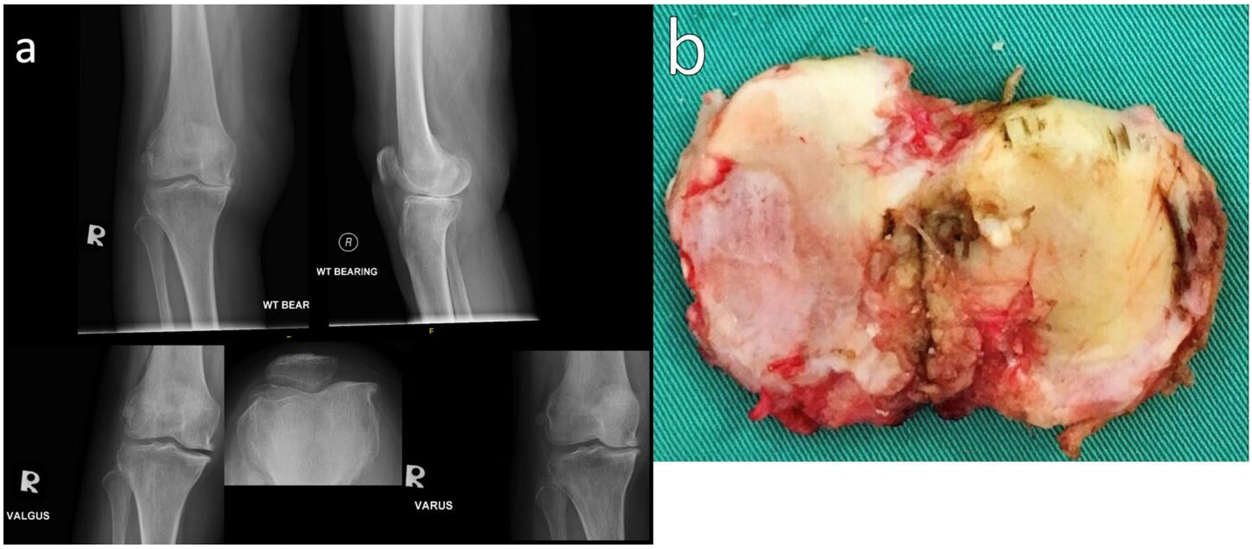

Fig. 1 **a** Radiographs assessed using the Oxford Radiological Decision Aid (ORDA). (**b**) The tibial "biscuit" was assessed for lateral compartment wear and photographed for evaluation

space narrowing; grade 3—moderate osteophytes and/or definite joint space narrowing; and grade 4—large osteophytes, severe joint space narrowing, and/or bony sclerosis [16, 17]. The skyline view was also evaluated to determine the severity of OA at the patellofemoral joint (PFJ), with a particular focus on the presence of OA in the lateral facet.

The modified Keyes classification was used to assess anterior cruciate ligament (ACL) function. The lateral radiograph of the knee was scrutinized and graded according to the site of wear and position of the femur. Grade 1 indicates an intact, functioning ACL with wear limited to the anterior compartment. Grade 2 suggests a degenerated or torn ACL, with erosion extending to the posterior margin of the tibial plateau. Grade 3, indicative of a non-functioning ACL, shows subluxation of the tibia relative to the femur. These radiographic assessments were conducted by three observers: two orthopaedic specialists with completed arthroplasty fellowship training and one orthopaedic postgraduate trainee.

Knee morphology

During surgery, the tibial surface wear site, involvement of the lateral compartment (both tibia and femur), and the status of the ACL were documented. A photograph of the tibial cut was obtained and later assessed by an independent observer. Cartilage wear on the weight-bearing portion of the lateral femoral condyle was graded according to the severity of cartilage wear as described by Weidow et al. [18]

1. Grade 0: No visible changes in the cartilage.
2. Grade 1: Cartilage fibrillation.
3. Grade 2: Partial cartilage loss without visible bone.
4. Grade 3: Full-thickness cartilage loss with visible bone.
5. Grade 4: Bone attrition.

In this study, intact full-thickness cartilage was defined as Weidow Grades 0–1, while full-thickness cartilage loss was defined as Weidow Grades 3–4. The ACL was considered functionally intact if its fibres were continuous from origin to insertion and exhibited a hard endpoint on clinical assessment. Cartilage on the medial and lateral tibial plateaus was analyzed individually from the digital photographs of the excised tibial biscuit. The medial tibial plateau was divided into three zones: anterior, middle, and posterior thirds, with the zone showing full-thickness cartilage wear (Weidow Grades 3 and 4) documented. The cartilage on the weight-bearing part of the lateral tibial plateau was described and graded based on the worst lesion observed.

Statistical analysis

Statistical analyses were conducted using SPSS software version 25.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as means ± standard deviations, while categorical variables were presented as frequencies and percentages. Intra-observer reliability was assessed using intraclass correlation coefficients. The inter- and intra-observer reliability for all radiographic components ranged from 0.76 to 1, while the reliability for intraoperative assessments ranged from 0.73 to 0.94. Comparisons of the modified Keyes classification across different subgroups (defined

Table 1 Demographic characteristics of patients by gender

Variables	Male	Female	Total
Patients, n	55	128	183
Age, years	68.0 ± 8.2	66.4 ± 7.6	67.0 ± 7.7
BMI	29.3 ± 4.6	29.7 ± 5.5	29.6 ± 5.2
Knees, n	62	145	207
Ethnicity			
Malay	17	47	64
Chinese	29	53	82
Indian	10	25	35
Others	0	2	2
Preoperative HKA angle, °	− 5.7 ± 5.7	− 6.1 ± 6.3	− 5.9 ± 6.2

Data are presented as the mean ± standard deviation unless otherwise indicated Body mass index

HKA hip-knee-ankle (negative value indicates varus, positive value indicates valgus)

by compartment involvement) were performed using the χ^2 test. Statistical significance was set at $p < 0.05$.

Results

A total of 183 patients were recruited, with 207 knees assessed. The cohort consisted of 128 women and 55 men, with a mean age of 67.0 ± 7.7 years (range 51–90 years). All patients had knee varus deformity with medial compartment involvement (KL grade 3–4). The demographic characteristics are detailed in Table 1.

Radiographs

Involvement of lateral compartment

Out of the 207 knees, 169 (81.6%) patients had a KL grading of two or less of the lateral compartment. Amongst the 38 (18.4%) that had lateral compartment involvement, only six (2.9%) knees were identified to have total loss of articulating cartilage, KL grade 4.

Involvement of patellofemoral joint (PFJ)

A total of 164 knees (79.2%) had no identifiable lateral PFJ wear (KL grades 1 and 2). Among the patients with no lateral compartment involvement, there were 31 knees (18.6%) with lateral compartment wear of the PFJ. The patterns of wear and the severity of the disease are summarized in Table 2 and Fig. 2.

Table 2 Distribution of OA patterns in patients with varus OA undergoing TKA

	Modified Keynes Classification			
Compartments	1	2	3	Total
Isolated medial	79	38	21	138
Medial + Lateral	15	7	4	26
Medial + PFJ	21	9	1	31
Tricompartmental	2	4	6	12
Total	117	58	32	207

OA: Osteoarthritis, TKA: Total Knee Arthroplasty, PFJ: PatelloFemoral Joint

Status of ACL based on radiographs

The status of the ACL was assessed using the modified Keyes classification [19]. A total of 117 knees (56.5%) were classified as grade 1, while 58 knees (28%) and 32 knees (15.5%) were classified as grades 2 and 3, respectively.

Suitability for a medial UKA

Based on the ORDA, 79 knees (38.2%) from our cohort had isolated medial compartment OA with no involvement of the lateral tibiofemoral or lateral patellofemoral compartments and an intact ACL, as determined by a grade 1 modified Keyes classification.

Operative findings

Intra-operatively, the ACL was found to be intact in 158 knees (76.3%), which correlated well with the site of tibial wear. An intact ACL typically causes wear in the anterior and middle thirds of the tibia, with the posteromedial plateau typically remaining unworn. We observed that 172 knees (83.1%) had sparing of the posterior third of the tibia.

Additionally, the lateral compartments were largely spared, with only 48 lateral tibial plateaus (23.2%) and 35 lateral femoral condyles (16.9%) showing involvement. Lateral patellofemoral wear was identified in 68 knees (33%). Based on intraoperative findings, 84 knees (40.6%) exhibited isolated anteromedial tibial wear and a functional ACL. Tibial plateau dimensions in our study population measured 45.3 ± 2.5 mm in the anteroposterior (AP) direction and 63.7

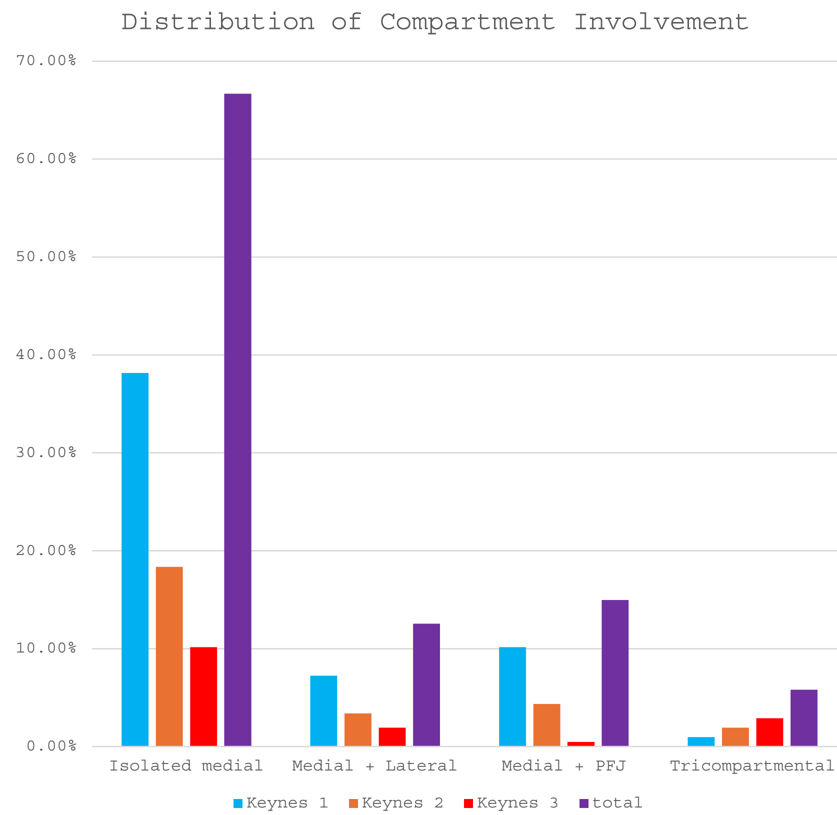

Fig. 2 Distribution of compartment involvement in varus knee osteoarthritis (OA). Proportions of compartments affected were classified into isolated medial involvement, combinations with the lateral or patellofemoral joint (PFJ) compartments, and involvement of all three compartments

± 7.6 mm in the mediolateral (ML) direction. Secondary analysis revealed no correlation between ethnicity, BMI, or age with the involvement of the lateral compartment, patellofemoral joint, or ACL integrity.

Discussion

The initial criteria for UKA suitability were described by Kozinn and Scott in 1989. These criteria included patients with isolated medial or lateral compartment involvement, age younger than 60 years, weighing less than 82 kg, an angular deformity less than 15° that is passively correctable, flexion contracture less than 5°, and a range of motion greater than 90°. Patients with high activity levels, evidence of PFJ OA, presence of chondrocalcinosis, lateral compartment osteophytes, inflammatory arthritis, and non-functional ACL were considered inappropriate for a UKA [20]. These criteria were introduced because historically, UKAs were associated with higher revision rates compared to TKAs.

Advancements in surgical technology, implant design, and instruments, as well as a better understanding of knee biomechanics and prosthesis, have led to the evolution of patient selection methods for UKA. The ORDA was introduced to establish a more objective method for patient selection based on five evidence-based criteria to improve patient selection, which requires bone-on-bone contact on the medial tibiofemoral joint, a functionally-intact ACL, full-thickness lateral cartilage, a functionally normal MCL on valgus stress view, and an acceptable patellofemoral joint [21].

Wang et al. in 2018 demonstrated that 48.2% of patients in a Chinese population scheduled for TKA had wear patterns and joint conditions suitable for medial UKA [22]. Therefore, we decided to prospectively observe the knee pathomorphology of varus arthritic knees in the Southeast Asian population. In our study, 38.2% of patients with varus knee arthritis in five public hospitals in the Klang Valley can be considered suitable candidates for UKA based on ORDA. This approach significantly reduces the selection constraints for UKA. Pandit et al. [23] observed approximately 1,000 patients with a UKA, many of whom were unsuitable based on the Kozinn and Scott criteria, and found that prosthesis survival rates were similar regardless of patient age, weight, activity level, or presence of PFJ OA.

Awareness of the evolving changes in selection criteria is crucial as our patients are becoming younger and more active, which translates to a higher demand for better surgical outcomes. UKA can be performed in a shorter time with a smaller incision, resulting in reduced pain, faster rehabilitation, and earlier discharge. In the long term, UKA offers more bone stock for revision surgery, lower morbidity, more normal knee kinematics, and a more"forgettable"joint. The risk of operative complications, such as myocardial infarction, venous thromboembolism, cerebrovascular events, and deep infections, is significantly lower in patients undergoing UKA compared to TKA [24].

In addition to the better risk profile, comparative economic analyses between UKA and TKA favour UKA. Shankar et al. demonstrated shorter surgical times, fewer transfusions, and shorter hospital stays for UKA patients. Hospital direct and total costs were significantly lower for UKA patients [25]. This is also demonstrated by Xie et al. [26]. However, in the long term, the costs may be comparable if revision surgery is needed [27].

Despite the advantages of UKA compared to TKA, its adoption has been somewhat lagging. One reason is that multiple joint registries report higher revision rates for UKA compared to TKA. This is especially true for lower-volume surgeons, who have a revision risk four times higher than high-volume surgeons [28]. A higher volume of UKA procedures in a surgeon's practice is a significant factor in reducing revision rates [28]. However, widening the indications for UKA increases its utilization, improving surgeons'technical competency and consequently reducing complication and revision rates.

Epidemiological studies have shown that Asians have a higher predilection for lateral compartment osteoarthritis compared to their Caucasian counterparts [29]. Despite this, our experience shows that most knee arthritis cases still involve the medial compartment, and many knees have an intact ACL. We were slightly more cautious regarding the presence of lateral patellofemoral joint (PFJ) wear and considered cartilage loss as a contraindication instead of bone loss as advocated by Pandit et al. [23] The utilization of UKA in our population is quite attractive, as many Asian customs require deep knee flexion. Performing prayers in Buddhism, Hinduism, and Islam, as well as customary floor seating for meals, often requires deep knee flexion in positions like"seiza"or"Indian-style."

National database analyses from Korea and Japan show that, similar to the US, the utilization of UKAs is increasing more rapidly than TKAs. The notion of compartment preservation is increasingly attractive due to the discussed advantages. However, the smaller anatomy of Asians, including a smaller and narrower proximal tibia, presents a risk of tibial plateau fractures. The rates of postoperative tibial plateau fractures are significantly higher among Asian patients [30], especially with cementless tibial components, as reported mainly in Korea and Japan.

There are limitations in our study. Although we performed recruitment in five large hospitals in the Klang Valley, the hospitals are mainly public health institutions. A significant amount of TKAs are also performed in private hospitals, and we could not analyze this cohort of patients. However, because patients going to private hospitals are afforded shorter waiting lists, we presume that these patients have similar, if not less severe wear morphology as those patients that we did analyze. The use of different prosthetic systems, each with distinct sizing and design geometries, limited the ability to directly correlate tibial anatomical measurements with specific implant sizes. Standardization of implant type in future studies would enable more consistent and clinically relevant analysis.

Conclusion

In summary, a significant amount of patients undergoing TKA in Kuala Lumpur could be suitable candidates for UKA, as indicated by radiographic and intra-operative findings. Survivorship of UKAs is expected to improve with advances in material technology and the adoption of robotic-assisted techniques. The benefits of UKA, including the preservation of normal knee kinematics, reduced soft tissue trauma, and superior functional outcomes, make it a compelling option for treating knee OA. These advantages should prompt knee surgeons to consider UKA as a viable alternative to TKA even in patients with advanced arthritis.

Author contribution KWL, KAA and FCH were major contributors in writing the manuscript. AMM, SHS, JAL and SKT were involved in data collection, analysed and interpreted the patient data. All authors read, revised and approved the final manuscript.

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Data availability The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Human ethics and consent to participate This study was approved by the Malaysian Research and Ethics Committee (No: NMRR- 19 - 2960 - 49653). Written informed consent was obtained from all patients. All methods were carried out in accordance with the Declaration of Helsinki.

Competing interests The authors declare no competing interests.

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