Archives of Orthopaedic and Trauma Surgery (2019) 139:113–120
https://doi.org/10.1007/s00402-018-3069-8

KNEE ARTHROPLASTY

A novel preoperative scoring system for the indication of unicompartmental knee arthroplasty, as predictor of clinical outcome and satisfaction

Alexander Antoniadis[1] · Dimitris Dimitriou[1] · Jean Pierre Canciani[2] · Naeder Helmy[1]

Received: 15 July 2018 / Published online: 10 November 2018

Abstract

Introduction Proper patient selection is a crucial factor for the outcome of the unicompartmental knee arthroplasty (UKA). However, there is still not a clear consensus on which patients could benefit the utmost from a UKA. The purpose of this prospective study was to introduce a novel, preoperative, predictive score (Unicompartmental Indication Score, UIS) to aid proper patient selection in UKA.

Materials and methods A total of 152 patients with an average age of 68 years and a mean follow-up of 27 months were evaluated preoperatively with the UIS and postoperative at every follow-up. Correlation analysis was applied to identify potential relationships between the UIS, functional outcomes, pain relief, patient satisfaction, and range of motion. The ROC analysis was used to identify the best cutoff value of the UIS, which would have predicted an optimal outcome following UKA.

Results The majority of the patients (91%) were satisfied with the operation, with 61% reporting excellent and 30% good satisfaction. The UIS was positively correlated to the postoperative Knee Society Score (KSS) for both pain ($r=0.26$, $p<0.001$) and function ($r=0.31$, $p<0.001$). The UIS was also positively correlated to the patient satisfaction ($p=0.46$, $p<0.001$) and maximum postoperative flexion ($r=0.25$, $p<0.001$). The ROC analysis provided an ideal cutoff for UIS at 25 points (sensitivity: 75%, sensibility: 93%, area under the curve: 86%). At a mean follow-up of 27 months (range 24–37), we observed three revisions in 152 consecutive UKA with a mean UIS of 27 points (range 20–30).

Conclusions The newly introduced UIS score might be a reliable preoperative scoring system to predict patients with excellent satisfaction, functional outcome, pain relief and possibly implant survivorship following UKA, and therefore, could help the proper patient selection and decision-making in UKA.

Level-of-evidence Prospective study, II.

Keywords Unicompartmental knee arthroplasty (UKA) · Indication · Clinical Outcome · Patient-reported outcomes · Predictive score · Patient satisfaction · Revision · Scoring system

Introduction

Knee osteoarthritis (OA) is a leading cause of disability worldwide [1], mostly due to pain and functional limitations [2, 3]. Unicompartmental knee arthroplasty (UKA) is considered an excellent alternative to total knee arthroplasty (TKA) in the treatment of unicondylar femoro-tibial degeneration with reduced mortality and fewer complications [4]. Furthermore, UKA preserves the unaffected from OA structures, such as the cruciate ligament and the patellofemoral joint, which provides in turn near-normal kinematics [5], increased range of motion [6] and stable patellofemoral contact force and pressure [7], respectively.

Dimitris Dimitriou contributed equally to this work.

✉ Alexander Antoniadis
drantoniadis@outlook.com

[1] Department of Orthopaedics and Traumatology, Bürgerspital Solothurn, Solothurn, Switzerland

[2] Centre Hospitalier Prive Saint Gregoire, Saint-Grégoire, France

Up to date, there is no clear consensus regarding the indications and contraindications to UKA. Since Kozinn et al. [8] published their recommendations on UKA 1989, a lot has changed. Despite these well-established recommendations, their validity is often questioned in the literature, and the classic indications proposed from Kozinn, are gradually revised, with only some issues remaining controversial [9]. Age and increased body-mass-index (BMI) are no longer considered a contraindication to UKA [10–12]. Similarly, it has been reported that patellofemoral joint arthritis, with or without anterior knee pain, is no longer a contraindication in patients undergoing UKA [13]. Another area of controversy is whether to perform a UKA in patients with anterior cruciate ligament (ACL) deficiency. Current data suggest that patients with primary anteromedial OA and secondary degenerative ACL deficiency should be considered as possible candidates to UKA with good short-to-mid-term outcome and without increased risk of UKA failure [14], whereas patients with primary traumatic ACL deficiency and secondary posteromedial OA might show increased risk of failure rates by wear and tibial loosening due to the knee instability [15].

Several studies concluded that proper patient selection is a crucial factor in the outcome of the UKA [16, 17] and the higher incidence of UKA failure compared to TKA have been associated, apart from the implant malposition [18, 19] and surgical technique [20], to not strictly correct UKA indications [21]. Indeed, it is still not clear which patients could benefit the utmost from a UKA regarding pain relief, functional outcome, satisfaction, and implant survivorship. Therefore, the purpose of the current, prospective study was to introduce a novel, preoperative, predictive scoring system (Unicompartmental Indication Score, UIS) to aid proper patient selection and decision-making in UKA. We hypothesized that patients with higher UIS would have a better outcome compared to patients with lower UIS.

Materials and methods

Study design and participants

All the patients gave informed consent prior to participation, and the study was approved by the institutional review board and the ethical committee. This prospective study was conducted entirely at one of the senior author institution. The senior author is a high-volume knee surgeon, who performs more than 250 knee arthroplasties a year. From January 2014 until January 2016, all the patients presented in the clinic with symptomatic knee osteoarthritis waiting for a knee arthroplasty were considered as potential candidates for the study. The follow-up period ended on January 2018, to achieve a minimum follow-up of 2 years. Exclusion criteria were: three-compartment knee osteoarthritis, age < 40 years old and previous joint arthroplasty (TKA on the contralateral side or THA on either side, as a previous arthroplasty, could potentially affect the rehabilitation process and the functional scores).

Unicompartmental indication score (UIS)

Independent variables of the score

Independent variable was considered each factor reported in the literature, which could potentially influence the outcome of the surgery (Table 1). Specifically: age, BMI,

Table 1 UIS

Independent variable	1-point	2-points	3-points
Age (years)	50–60	60–80	> 80
Cause of symptoms	Inflammatory	Chondrocalcinosis	Osteoarthritis/osteonecrosis
BMI (kg/m^2)	≥ 40	30–40	≤ 30
Past history in the affected knee	Trauma[a]	Osteotomy	None
Clinical ACL function	None	Partial[b]	Normal
Fixed varus/valgus (°)	≥ 10	5–10	0–5
Patellofemoral Degeneration (modified Altman) [23]	Grade 3 with or without subluxation	Grade 1–2	Grade 0
Range of motion (flexion/extension°)	100/15/15	120/15/15	≥ 120/0/0
Affected compartment status (Kellgren-Lawrence) [22]	Grade 2	Grade 3	Grade 4
Opposite compartment status (Kellgren–Lawrence) [22]	Grade 2	Grade 1	Grade 0

[a]Previous trauma was considered as any trauma that did not result in significant deformity of proximal tibia or distal femur (including meniscus tear, anterior cruciate ligament (ACL) rupture, etc.)

[b]Partial clinical ACL function was considered increased anteroposterior laxity without rotatory instability

cause of symptoms, previous trauma or surgery in the affected knee, clinical ACL deficiency (evaluated with the Lachman test, anterior drawer, and pivot shift test; a partial function of ACL was defined as low patient's sensation of instability, asymmetric laxity in Lachman test but lack of pivot shift test); fixed varus or valgus knee (meaning varus or valgus deformity which was not corrected after applying valgus or varus stress, respectively, assessed using varus/valgus stress X-rays); range of motion (ROM) and radiologic assessment of the affected, contralateral and patellofemoral compartment according to Kellgren–Lawrence OA classification [22] and modified Altman [23] using knee X-rays (anterior-posterior, lateral, Rosenberg, skyline Merchant view).Each factor added 1–3 points to the score, and finally, the points were summed to give the definitive UIS (Table 2). All the patients were also evaluated preoperatively with the Knee Society Score (KSS) for pain and function [24].

Table 2 Patient demographics with preoperative status

Parameter	Category (*N*)	Percentage (%)
Gender	Male (94)	62
	Female (58)	38
Side	Left (79)	52
	Right (73)	48
UKA	Medial (123)	81
	Lateral (29)	19
BMI (kg/m^2)	≥ 40 (8)	6
	30–40 (54)	36
	≤ 30 (90)	60
Cause of symptoms	Osteoarthritis/osteonecrosis (135)	88
	Chondrocalcinosis (13)	9
	Inflammatory arthritis (4)	3
Age (years)	50–60 (17)	11
	60–80 (116)	76
	≥ 80 (19)	13
Degree of degeneration in the affected compartment	0 (0)	0
	1 (0)	0
	2 (6)	4
	3 (60)	39
	4 (86)	57
Degree of degeneration in the contralateral compartment	0 (30)	20
	1 (52)	34
	2 (52)	34
	3 (18)	12
	4 (0)	0
Degree of patellofemoral joint degeneration	0 (6)	4
	1 (63)	41
	2 (75)	50
	3 (8)	5
Previous knee operation	None (135)	89
	ACL reconstruction (3)	2
	Arthroscopic meniscus resection (7)	3
	Tibia plateau osteosynthesis (4)	3
	Correction osteotomy (3)	2
ACL function	Intact (123)	81
	Partial (5)	33
	None (24)	16
Range of motion (°)	≥ 120/0/0 (125)	82
	120/15/15 (15)	10
	100/15/15 (12)	8
Hip-knee-angle under stress (°)[a]	0–5 (64)	42
	5–10 (65)	43
	≥ 10 (23)	15

Meniscus resection of the contralateral compartment

[a]For patients with varus knee, a valgus stress was applied, whereas for patients with valgus test a varus test was applied

Surgical technique and postoperative care

All the operations were performed in a standardized manner, under general or spinal anesthesia in the supine position, using a conventional operating table with the knee flexed in 90° for the skin incision. The patients who received a medial or lateral UKA underwent a minimally invasive medial subvastus or lateral parapatellar approach, respectively. The patella was displaced laterally but never everted. The ACL, the opposite tibiofemoral and the patellofemoral compartment were evaluated intraoperatively, and all the osteophytes were removed. Patient-specific cutting blocks were used for the tibial cuts. Subsequently, gaps were checked with spacer blocks. Extramedullary alignment rods were used to control alignment after the cuts. Primary cemented implants (GMK®, Medacta International, Castel San Pietro, CH) were used in all cases, and all patellae were not resurfaced. No lateral or retinacular releases were necessary. No drains were used. Full weight-bearing was allowed the day after surgery as well as active range of motion exercises. Patients were discharged when able to mobilize for daily activities safely and pain is controlled with oral medications. All patients were treated with Enoxaparin 40 mg sc. once daily as deep venous thrombosis prophylaxis for 30 days.

Clinical evaluation

Postoperatively, the patients were followed-up clinically and radiographically at 3 months and yearly. Interviews with patients were contacted personally in the clinic. The Hip-Knee-Angle (HKA) was assessed pre- and postoperative on weight-bearing long leg views. The patient satisfaction was assessed using a four-point Likert Scale for responses: "excellent," "good," "poor" and "terrible."

Statistical analysis

Descriptive statistics used frequencies and percentages to present the data. All parameters were tested with the Kolmogorov–Smirnov test for normality. When the criteria for normality were met, a two-tailed paired t-test was used to compare pre- and postoperative outcomes. Otherwise, the Wilcoxon signed-rank test was applied. The Pearson and Spearman correlations were used to identify a potential relationship between continuous variables such as the UIS and postoperative KSS for function and pain, and ordinary variables such as patient satisfaction, respectively. The level of significance was set at $a = 0.05$. The Receiver-Operator Characteristic (ROC) curve was used to identify the best cutoff value of the UIS, which would have predicted an optimal or a non-optimal outcome. For the ROC analysis optimal outcome was considered no revision surgery, excellent patient satisfaction and KSS score of more than 80 in both pain and function. Otherwise, the outcome was considered as non-optimal. The patients were then divided into two groups according to the cutoff value in ROC curve (group 1: UIS > 25 points, group 2: UIS ≤ 25 points), and the postoperative patient satisfaction, as well as clinical outcomes, were then compared between groups. All the statistical analyses were performed using SPSS version 22 software (SPSS Inc., Chicago, Illinois).

Results

Participants

A total of 511 patients presented from January 2014 until January 2016, in the outpatient clinic with symptomatic knee OA, requiring a knee arthroplasty. Around 66% ($n = 337$) of the patients had a three-compartment OA, and therefore a TKA was performed instead. Seventeen patients had already a TKA in the contralateral side or total hip arthroplasty (THA) in either side and therefore, excluded from the study. Finally, a total of 152 patients (male: 94 female: 58) with an average age of 68 years (range 41–90) met the inclusion criteria for the current study (Fig. 1). The mean follow-up was 27 months (range: 24 to 37). Twenty-nine patients received a lateral UKA whereas 123 patients received a medial UKA (Table 1). The mean preoperative KSS score for pain and function was 52 (range 35–65) and 56 (range 35–68), respectively. The preoperative mean preoperative UIS score was 27 (range 20–30).

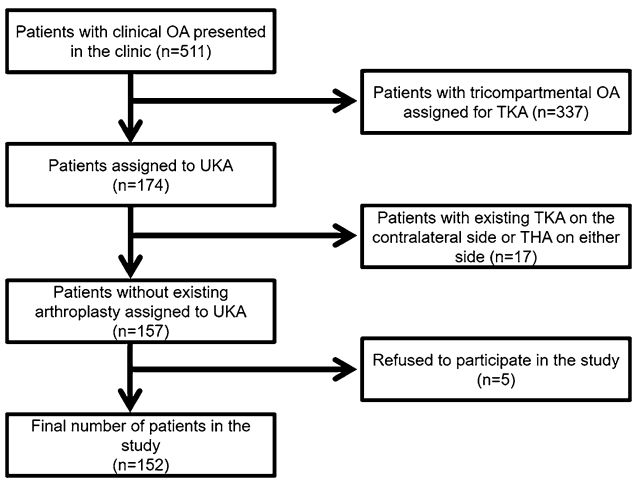

Fig. 1 Flowchart of patients' recruitment. *OA* osteoarthritis, *TKA* total knee arthroplasty, *UKA* unicompartmental knee arthroplasty, *THA* total hip arthroplasty

Complication rate and revision

At a mean follow-up of 27 months, we recorded two cases of postoperative hematoma, which required surgical evacuation, and one case of early deep infection which was treated with exchange of the inlay component, debridement, and intravenous antibiotic administration. No other complications were recorded.

Radiographic outcomes

The postoperative X-rays (anterior–posterior, lateral and weight-bearing long leg view) were evaluated by one orthopedic surgeon blinded to patients' clinical details and preoperative planning. Measurement of HKA showed a mean value of 174.3° (SD 3.3°) varus preoperative compared to 176.3° (SD 2.9°; $p > 0.5$) postoperative. The difference between final implant position compared to preoperative planning showed a mean of 0.5° (SD 2.3°; $p < 0.01$) for the tibial varus/valgus and a mean difference of 0.3° (SD 2.8°; $p = 0.2$) for the tibial slope (Table 3). There were no signs of loosening of the tibial or femoral component at the latest follow-up.

Functional scores and patient satisfaction

Postoperative functional scores improved significantly from the preoperative value. The mean KSS-pain and KSS-function increased from 52 to 56, preoperative to 95 and 96 at the 1-year follow-up, respectively. The majority of the patients (91%) were satisfied with the operation, with 61% (93 out of 152) reporting excellent and 30% (46 out of 152) good satisfaction, whereas only 9% (13 out of 152) of the patients reported poor satisfaction. The preoperative KSS-function and KSS-pain were not correlated to patient satisfaction or postoperative KSS-Pain or KSS-Function. The patient satisfaction, KSS-Pain, and KSS-Function were not correlated with the postoperative HKA value. The UIS was positively correlated to the postoperative KSS score for both pain ($r = 0.26$, $p < 0.001$) and function ($r = 0.31$, $p < 0.001$). The UIS score was also positively correlated to the patient satisfaction ($p = 0.46$, $p < 0.001$) and maximum postoperative knee flexion ($r = 0.25$, $p < 0.001$).

ROC analysis

The ROC curve analysis provided an ideal cutoff for UIS at 25 points, with a sensitivity of 75%, a sensibility of 93%, and area under the curve 85% (Fig. 2).

Analysis of groups generated according to UIS cutoff value

The majority of the patients (79%, 120 of 152) had a preoperative UIS of more than 25 (range 25–30) points, whereas only 32 (21%) patients had a score of equal or less than 25 (range 20–25) points. No significant difference was observed regarding demographics (age, BMI gender) and preoperative HKA between groups (Table 3). The postoperative KSS-Pain and KSS-Function score were significantly higher in

Table 3 Patient characteristics, pre- and postoperative functional score and patient satisfaction

Parameter	UIS ≥ 25 ($n = 120$)	UIS ≤ 25 ($n = 32$)	Significance (***p* value**)
BMI (kg/m^2)	30 (18, 45)	28 (17, 45)	0.06
Age (years)	69.3 (41, 90)	68.4 (50, 90)	0.744
Gender (male, female)	63% (76), 37% (44)	56% (18), 44% (14)	0.68
Preoperative KSS-function	58 (35, 68)	54 (35, 65)	**0.001***
Preoperative KSS-Pain	54 (38, 65)	45 (35, 61)	**0.001***
KSS-Function at 1-year follow-up	96 (80, 100)	75 (70, 100)	**0.001***
KSS-Pain at 1-year follow-up	93 (86, 100)	79 (70, 100)	**0.001***
Preoperative HKA	175 (168, 190)	175 (168, 190)	0.79
Postoperative HKA	179 (177, 182)	179 (175, 183)	0.71
Satisfaction (%)	71% (85)	25% (8)	**0.001**
Excellent	26% (31)	47% (15)	**0.001***
Good	3% (4)	28% (9)	**0.001***
Poor	0%	0%	
Terrible			
Preoperative flexion (°)	120 (90, 135)	118 (90, 132)	0.71
Postoperative flexion (°)	140 (125, 147)	130 (115, 140)	**0.001***

The values were given in mean value and range

KSS knee society score, *HKA* hip-knee-angle

*Indicates statistically significant difference ($p < 0.05$)

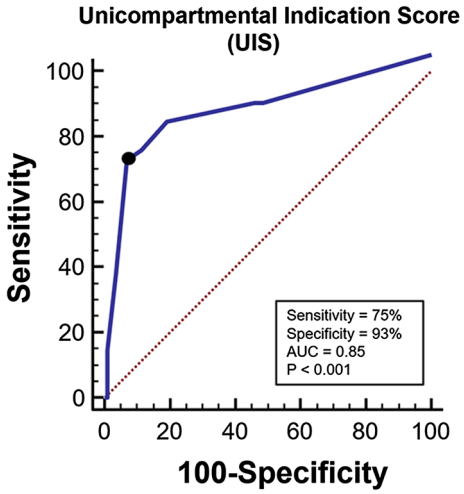

Fig. 2 The results of the ROC analysis are shown. The black dot indicates the point with the higher Youden index [26] for UIS at 25 points

group 1 in comparison to group 2. In group 1 (UIS > 25 points), 71% (85 out of 120) and 26% (31 out of 120) of the patients reported an excellent and good satisfaction, respectively, whereas only 3% (4 out of 120) reported a poor satisfaction. No patient reported a poor or terrible outcome in group 1. In group 2 (UIS ≤ 25 points), only 25% (8 out of 32) were entirely satisfied with the UKA, whereas 47% (15 out of 32) and 28% (9 out of 32) reported a good and poor outcome, respectively. The maximum postoperative knee flexion was also higher in the group 1 compared to group 2 (140° versus 130°).

Discussion

UKA is considered an excellent alternative to total knee arthroplasty (TKA) in the treatment of unicompartmental tibiofemoral osteoarthritis, with high patient satisfaction and survival rates [25]. However, proper patient selection is a requirement for successful surgery [16, 17] and still, there is no clear consensus on which patient could benefit the utmost of a UKA. The purpose of the current study was to introduce a novel, preoperative scoring system, which could aid proper patient selection and decision-making in UKA. The results of this prospective cohort showed that the newly introduced UIS could accurately predict excellent clinical outcomes, patient satisfaction and high implant survivorship following a UKA (sensibility 75%, sensitivity 93%, AUC 85%, $p < 0.001$). Furthermore, the radiographic findings have not biased our results as no outlier was found in our cohort in respect to radiographic accuracy of implant positioning. To the best knowledge of the authors, this is the only cohort to present a preoperative, prediction score, as an indicator of proper patient selection in UKA.

The UIS includes several well-established parameters, which were proved to affect the clinical outcome following a UKA (Table 1). The area under the ROC curve for the UIS was 85% indicating an excellent test [26], with a sensitivity of 75% and a specificity of 93%. The optimal cutoff value for UIS according to ROC was 25 points. The majority of the patients with UIS of more than 25 points were satisfied with the operation with 97% reporting an excellent or good satisfaction and only 3% reporting a poor satisfaction. On the contrary, patients with a UIS of equal or less than 25 points had a significantly lower postoperative satisfaction, with most of the patients (47%) reporting a good satisfaction, and 28% of the patients reporting a poor satisfaction (Table 3). Only 25% of the patient in group 2 reported an excellent satisfaction. The postoperative KSS-Pain and KSS-Function were significantly higher in the group 1 compared to group 2 (Table 3). The maximum postoperative knee flexion was also higher in the group 1 compared to group 2 (140° versus 130°). These data suggest that the UIS could potentially identify patients, which would benefit the utmost from a UKA in terms of pain relief, function, postoperative satisfaction and maximum knee flexion.

Recently, patient satisfaction has received increased attention as an essential aspect of medical care and a fundamental factor influencing the clinical outcome and the quality of life following a surgery [27]. However, only a relatively few numbers of studies reported the patient satisfaction following UKA. Von Arnel et al. [28] reported a satisfaction rate of 96% and 93% in patients under 55 and over 55 years old, respectively. Lee et al. [29] found a 92.2% satisfaction rate in the Asian population undergoing UKA. In accordance with the literature, the satisfaction rate in the current study was 91% with the 61% of the patients reporting excellent and 30% reporting a good outcome. Patient satisfaction was significantly correlated with higher postoperative function and pain relief, meaning that patients with higher functional capacity and lower pain postoperative were more likely to be satisfied with the outcome of the UKA. Also, patient satisfaction was positively correlated with the UIS, suggesting that patients with higher preoperative UIS were most likely to be satisfied with the result of the UKA.

Recent evidence suggests that UKA might be an excellent alternative to TKA in patients with unicompartmental tibiofemoral OA [25]. However, there are still conflicting data in the literature regarding long-term implant survivorship and revision, following UKA. Specifically, Berger et al. [30] and Argensen et al. [25] reported a 98% and 94% 10-year survival rate in Miller-Galante design UKA, respectively. Niinimäki et al. [31] using the data of the Finnish Arthroplasty Register, reported a survivorship rate of 89.4% at 5 years and 80.6% at 10 years in 4713 UKA, whereas the corresponding survivorship of the TKA were 96.3% and 93.3%, respectively. The most common mode of early implant

failure was aseptic loosening accounting for the 26% of the cases [32]. As for the reasons responsible for early failure, several studies support that implant malposition [19], surgical technique [20], and poor patient selection [33] are the primary factors affecting the long-term survivorship of the UKA. Nevertheless, regarding patient selection, the data in the literature are still conflicting and controversial. Precisely, Kuipers et al. [20]. in an attempt to identify the factors associated with early implant failure, studied retrospectively 437 oxford knee UKA with a 5-year survival rate of 84.7%. They concluded that younger patients and radiological absence of patellofemoral OA were the only factors that negatively affected the implant survivorship, whereas obesity, gender, and high surgeon UKA caseload did not affect the outcome. Berend et al. [34] on the contrary, in a retrospective study of 79 UKA reported a 78.8% 2-year survival rate, with BMI of 32 kg/m^2 associated with a reduction in survivorship, whereas age, gender disease severity, and implant design did not affect the outcome. Although the reason for this discrepancy in the literature is not known, we believe that it is more likely a combination of factors that affect the outcome, rather than a single patient factor independently. In our study, several parameters that could affect the outcome of UKA were included in the preoperative UIS (Table 1). At a mean follow-up of 27 months, we observed no implant failure in 152 consecutive UKAs with a mean UIS of 27 points (range 20–30) followed prospectively. Three revision surgeries were performed; however, the reason that lead to revision surgery (2 hematomas, 1 deep infection) was not directly related to the selection criteria included in UIS. These data suggest that patients with UIS more than 20 points might have a high implant survivorship and low revision rate, implying that they could be considered potential candidates for a UKA.

The current study should be interpreted in light of its potential limitations. The main drawback was the single-center design. It should be stated that all the UKA were performed from a high-volume knee arthroplasty surgeon, who performs more than 250 arthroplasties a year. Therefore, the results of this study might not reflect the outcomes of low-volume surgeons. Additionally, most of the patients in this study (91%) reported either excellent or good outcomes, and the major complication rate was extremely low (1.9%), at a mean 27-months follow-up. Furthermore, most of the patients included in the current study had a high UIS (mean 27 points, range 20–30). More patients should be recruited in future studies to determine the cutoff value of UIS score for poorer outcomes.

In conclusion, the result of the current study suggests that the newly introduced UIS might be a reliable preoperative scoring system to predict patients with excellent satisfaction, functional outcome, pain relief and possibly implant survivorship following UKA. To the best knowledge of the authors, this is the only cohort to present a preoperative, prediction score for UKA as an indicator of proper patient selection. According to the results of our study, the authors suggest that a UIS > 25 is considered a good indication score for patients being considered for UKA with high chances of excellent outcome. On the other hand, patients with a UIS of equal to or less than 25 points should be informed of the potential risk of lower satisfaction and clinical outcome in comparison to patients with UIS score of more than 25. A UIS < 20 is considered from the authors formally a contraindication, as no data are yet available to support implantation of UKA in these patients. More patients should be recruited in future studies to confirm the validity and accuracy of the UIS on a larger scale.

Funding There was no external funding source of funding in the current study.

Conflict of interest The authors declare that they have no competing interests.

References

1. Centers for Disease C, Prevention (2009) Prevalence and most common causes of disability among adults–United States, 2005. MMWR Morb Mortal Wkly Rep 58(16):421–426
2. Ayis S, Dieppe P (2009) The natural history of disability and its determinants in adults with lower limb musculoskeletal pain. J Rheumatol 36(3):583–591. https://doi.org/10.3899/jrheum.080455
3. Dominick KL, Ahern FM, Gold CH, Heller DA (2004) Health-related quality of life and health service use among older adults with osteoarthritis. Arthritis Rheum 51(3):326–331. https://doi.org/10.1002/art.20390
4. Morris MJ, Molli RG, Berend KR, Lombardi AV Jr (2013) Mortality and perioperative complications after unicompartmental knee arthroplasty. Knee 20(3):218–220. https://doi.org/10.1016/j.knee.2012.10.019
5. Patil S, Colwell CW Jr, Ezzet KA, D'Lima DD (2005) Can normal knee kinematics be restored with unicompartmental knee replacement? J Bone Jt Surg Am 87(2):332–338. https://doi.org/10.2106/JBJS.C.01467
6. Lyons MC, MacDonald SJ, Somerville LE, Naudie DD, McCalden RW (2012) Unicompartmental versus total knee arthroplasty database analysis: is there a winner? Clin Orthop Relat Res 470(1):84–90. https://doi.org/10.1007/s11999-011-2144-z
7. Price AJ, Oppold PT, Murray DW, Zavatsky AB (2006) Simultaneous in vitro measurement of patellofemoral kinematics and forces following Oxford medial unicompartmental knee replacement. J Bone Jt Surg Br 88(12):1591–1595. https://doi.org/10.1302/0301-620X.88B12.18306
8. Kozinn SC, Scott R (1989) Unicondylar knee arthroplasty. J Bone Jt Surg Am 71(1):145–150
9. Vasso M, Corona K, D'Apolito R, Mazzitelli G, Panni AS (2017) Unicompartmental knee arthroplasty: modes of failure and conversion to total knee arthroplasty. Jt 5(01):044–050
10. Pennington DW, Swienckowski JJ, Lutes WB, Drake GN (2003) Unicompartmental knee arthroplasty in patients sixty years of age or younger. J Bone Jt Surg Am 85-A(10):1968–1973

11. Tabor OB Jr, Tabor OB, Bernard M, Wan JY (2005) Unicompartmental knee arthroplasty: long-term success in middle-age and obese patients. J Surg Orthop Adv 14(2):59–63
12. Iacono F, Raspugli GF, Akkawi I, Bruni D, Filardo G, Budeyri A, Bragonzoni L, Presti ML, Bonanzinga T, Marcacci M (2016) Unicompartmental knee arthroplasty in patients over 75 years: a definitive solution? Arch Orthop Trauma Surg 136(1):117–123. https://doi.org/10.1007/s00402-015-2323-6
13. Beard D, Pandit H, Ostlere S, Jenkins C, Dodd C, Murray D (2007) Pre-operative clinical and radiological assessment of the patellofemoral joint in unicompartmental knee replacement and its influence on outcome. Bone Jt J 89(12):1602–1607
14. Engh GA, Ammeen DJ (2014) Unicondylar arthroplasty in knees with deficient anterior cruciate ligaments. Clin Orthop Relat Res 472(1):73–77. https://doi.org/10.1007/s11999-013-2982-y
15. Mancuso F, Dodd CA, Murray DW, Pandit H (2016) Medial unicompartmental knee arthroplasty in the ACL-deficient knee. J Orthop Traumatol 17(3):267–275. https://doi.org/10.1007/s10195-016-0402-2
16. Rodriguez-Merchan EC (2016) Unicompartmental knee osteoarthritis (UKOA): unicompartmental knee arthroplasty (UKA) or high tibial osteotomy (HTO)? Arch Bone Jt Surg 4(4):307–313
17. Luscombe KL, Lim J, Jones PW, White SH (2007) Minimally invasive Oxford medial unicompartmental knee arthroplasty. A note of caution! Int Orthop 31(3):321–324. https://doi.org/10.1007/s00264-006-0202-z
18. Kang KT, Son J, Baek C, Kwon OR, Koh YG (2018) Femoral component alignment in unicompartmental knee arthroplasty leads to biomechanical change in contact stress and collateral ligament force in knee joint. Arch Orthop Trauma Surg 138(4):563–572. https://doi.org/10.1007/s00402-018-2884-2
19. Liow MHL, Tsai T-Y, Dimitriou D, Li G, Kwon Y-M (2016) Does 3-dimensional in vivo component rotation affect clinical outcomes in unicompartmental knee arthroplasty? J Arthroplast 31(10):2167–2172
20. Kuipers BM, Kollen BJ, Bots PCK, Burger BJ, van Raay JJ, Tulp NJ, Verheyen CC (2010) Factors associated with reduced early survival in the Oxford phase III medial unicompartment knee replacement. Knee 17(1):48–52
21. Epinette JA, Brunschweiler B, Mertl P, Mole D, Cazenave A,, Knee (2012) French society for H. Unicompartmental knee arthroplasty modes of failure: wear is not the main reason for failure: a multicentre study of 418 failed knees. Orthop Traumatol Surg Res 98(6 Suppl):S124–S130. https://doi.org/10.1016/j.otsr.2012.07.002
22. Kellgren JH, Lawrence JS (1957) Radiological assessment of osteo-arthrosis. Ann Rheum Dis 16(4):494–502
23. Altman RD, Fries JF, Bloch DA, Carstens J, Mb D, Cooke T, Genant H, Gofton P, Groth H, Mcshane DJ (1987) Radiographic assessment of progression in osteoarthritis. Arthritis Rheumatol 30(11):1214–1225
24. Scuderi GR, Bourne RB, Noble PC, Benjamin JB, Lonner JH, Scott WN (2012) The new knee society knee scoring system. Clin Orthop Relat Res 470(1):3–19. https://doi.org/10.1007/s11999-011-2135-0
25. Argenson J-NA, Chevrol-Benkeddache Y, Aubaniac J-M (2002) Modern unicompartmental knee arthroplasty with cement: a three to ten-year follow-up study. JBJS 84(12):2235–2239
26. Cantor SB, Kattan MW (2000) Determining the area under the ROC curve for a binary diagnostic test. Med Decis Mak 20(4):468–470. https://doi.org/10.1177/0272989X0002000410
27. van Campen C, Sixma H, Friele RD, Kerssens JJ, Peters L (1995) Quality of care and patient satisfaction: a review of measuring instruments. Med Care Res Rev 52(1):109–133
28. Von Keudell A, Sodha S, Collins J, Minas T, Fitz W, Gomoll A (2014) Patient satisfaction after primary total and unicompartmental knee arthroplasty: an age-dependent analysis. Knee 21(1):180–184
29. Lee M, Huang Y, Chong HC, Ning Y, Lo NN, Yeo SJ (2016) Predicting satisfaction for unicompartmental knee arthroplasty patients in an Asian population. J Arthroplast 31(8):1706–1710
30. Berger RA, Meneghini RM, Jacobs JJ, Sheinkop MB, Della Valle CJ, Rosenberg AG, Galante JO (2005) Results of unicompartmental knee arthroplasty at a minimum of ten years of follow-up. JBJS 87(5):999–1006
31. Niinimäki T, Eskelinen A, Mäkelä K, Ohtonen P, Puhto A-P, Remes V (2014) Unicompartmental knee arthroplasty survivorship is lower than TKA survivorship: a 27-year finnish registry study. Clin Orthop Relat Res 472 (5):1496–1501
32. van der List JP, Zuiderbaan HA, Pearle AD (2016) Why do medial unicompartmental knee arthroplasties fail today? J Arthroplast 31 (5):1016–1021
33. 35. Aleto TJ, Berend ME, Ritter MA, Faris PM, Meneghini RM (2008) Early failure of unicompartmental knee arthroplasty leading to revision. J Arthroplast 23 (2):159–163
34. 36. Berend KR, Lombardi AV Jr, Mallory TH, Adams JB, Groseth KL (2005) Early failure of minimally invasive unicompartmental knee arthroplasty is associated with obesity. Clin Orthop Relat Res 440:60–66