




# Change in patellar height in medial and lateral unicompartmental knee arthroplasty: a clinical trial

Riccardo D'Ambrosi<sup>1,2</sup> · Francesco Rubino<sup>3,5</sup> · Chiara Ursino<sup>3,5</sup> · Ilaria Mariani<sup>4</sup> · Nicola Ursino<sup>1</sup> · Matteo Formica<sup>3,5</sup> · Julia Prinz<sup>6</sup> · Filippo Migliorini<sup>7,8</sup> 

Received: 24 July 2023 / Accepted: 13 November 2023  
© The Author(s) 2023

## Abstract

**Introduction** Evidence on patellar height changes following unicompartmental knee arthroplasty (UKA) is lacking. Therefore, this study compared the patella height in patients who underwent medial versus lateral UKA. Moreover, a subgroup analysis was conducted to investigate whether sex, age, and BMI of the patients exert an influence on the postoperative patellar height.

**Methods** Radiographs and hospital records of patients undergoing UKA were prospectively collected. Surgeries were performed by one author with long experience in UKA in a highly standardised fashion. The implants were fixed-bearing medial PPK (Zimmer Biomet, Warsaw, Indiana, USA) and fixed-bearing lateral ZUK (Lima Corporate, Udine, Italy). The patellar height was measured using the Insall–Salvati and Caton–Deschamps indices.

**Results** A total of 203 patients were included: 119 patients were included in the medial and 84 in the lateral UKA. The mean age of the patients was  $68.9 \pm 6.7$  years, and the mean BMI was  $28.1 \pm 4.1$  kg/m<sup>2</sup>. 54% (110 of 203 patients) were women. On admission, between-group comparability was found in age, BMI, sex, and length of the follow-up. No between-group and within-group difference was detected pre- and post-operatively in the Insall–Salvati and Caton–Deschamps indices in patients who have undergone medial versus lateral UKA. Concerning the subgroup analyses, no between-group and within-group difference was detected pre- and post-operatively in all comparisons according to sex, age, and BMI.

**Conclusion** No difference was found in patella height in patients who have undergone medial compared to lateral UKA. Furthermore, there was no evidence of an association between patient characteristics (sex, age, BMI) and patella height between medial and lateral UKA.

**Keywords** Unicompartmental knee arthroplasty · UKA · Patella height · Insall–Salvati · Caton–Deschamps

## Abbreviations

BMI	Body mass index
IS	Insall–Salvati
CD	Caton–Deschamps
UKA	Unicompartmental knee arthroplasty
OA	Osteoarthritis
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology

## Introduction

Osteoarthritis of the knee is a major health issue [1–3]. Unicompartmental knee arthroplasty (UKA) is a well-established treatment option in patients with medial or lateral unicompartmental OA since its introduction in 1975 [4–6]. UKA recreates joint space in the affected compartment [7–10]. Compared to total knee arthroplasty (TKA), the cruciate ligaments and extensor mechanism are spared in UKA, ensuring more physiologic kinematics [11–13]. UKA is associated with faster recovery, shorter hospitalisation, lower intraoperative blood loss, better functional outcomes and patient satisfaction, and greater postoperative range of motion than TKA [1, 14, 15]. Given the physiological alignment of the lower limb, approximately 90% of unilateral OA and UKA are at the medial compartment [16–20].

---

Julia Prinz and Filippo Migliorini have equally contributed to this study and share the last authorship.

---

Extended author information available on the last page of the article

Contraindications of UKA include high BMI, deformities, and restricted joint motion [21].

Patella height changes following TKA might result in anterior knee pain, midflexion instability, and reduced postoperative range of motion [22–25]. Lower BMI, women, and older age have been associated with a greater risk of patella height following TKA [26]. Other acquired risk factors for patellar height changes following TKA have been described, including removal of Hoffa's fat pad, scar tissue formation, intraoperative over-resection of the distal femur, and the type of surgical approach [27–32]. However, evidence on patellar height changes following UKA is lacking [33].

The present study compared the patella height in patients who underwent medial versus lateral UKA for UKA. Moreover, a subgroup analysis was conducted to investigate whether sex, age, and BMI of the patients exert an influence on the postoperative patellar height.

## Materials and methods

This study was conducted following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [34]. All procedures involving human participants in this study were performed in accordance with the ethical standards of the institutional and/or national research committee as well as the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all the participants. The present study was approved by the Ethics Committee of the San Raffaele University Hospital of Milan, Italy (CE 236/2017). Data from patients who have undergone elective primary UKA at our institution between 2018 and 2021 were prospectively collected.

The indication for surgery was isolated unicompartmental symptomatic OA grades III to IV according to the Kellgren–Lawrence rating score [35]. In all the cases, the anterior cruciate, medial collateral, and lateral collateral ligaments were functionally intact, as confirmed by magnetic resonance imaging (MRI) and clinical examination. Patients who had previous surgery of the affected knee (except arthroscopy for meniscectomy), varus/valgus deformities, flexion deficit greater than 15°, and insufficient anterior or posterior cruciate ligament were considered as exclusion criteria.

## Procedures

Surgery was performed by one author with long experience in UKA in a highly standardised fashion. The implants were fixed-bearing medial PPK (Zimmer Biomet, Warsaw, Indiana, USA) and fixed-bearing lateral ZUK (Lima Corporate, Udine, Italy). All patients were placed in a supine position

on a standard operating table under spinal anaesthesia. A standard medial or lateral parapatellar approach was used. Inspection of the patellofemoral and medial compartments was performed. All components were cemented using Refobacin Bone Cement R (Zimmer Biomet, Warsaw, Indiana, USA). An intraarticular drain was placed and removed on the first postoperative day. Enoxaparin sodium 4000 units subcutaneously daily for 45 days was used as thromboembolic prophylaxis.

The postoperative protocol was conducted following a previous report [36]. Briefly, both the patient groups followed the same rehabilitation protocol involving passive mobilisation from day one after the surgery. From day two, they started an active progressive mobilisation of the joint and assisted walking with two crutches. According to each patient's capability, a gradual increase in the load during walking was recommended, continuing with isometric muscle toning exercises until the total abandonment of walking aids.

## Assessment

Two independent observers (experienced orthopaedic surgeons) assessed the preoperative and minimum 24-month postoperative radiographs. The radiographic measurements were performed twice with an interval of a minimum of 4–6 weeks. The standardised postoperative radiographs were aligned under fluoroscopic guidance to obtain views parallel to the tibial component in the anteroposterior view and parallel to the femoral component in the lateral view with the knee flexed at 30° without weight-bearing [37, 38]. Data concerning patients' age, sex, BMI, and location of the UKA (medial or lateral) were prospectively collected. The patellar height was measured using the Insall–Salvati (IS) [39] and Caton–Deschamps (CD) [40] indices. Both indices are validated methods to assess patellar height in the lateral projection of the knee at 30° of flexion (Fig. 1) [41–43].

## Power analysis

An estimated sample of 71 subjects for each group was required to compare patellar height between medial and lateral UKA position with a two-sided Wilcoxon–Mann–Whitney test, given an index mean difference of 5, a standard deviation of 8 for both groups, a 5% alpha, and a 95% power. This sample had also a 99% power to detect a difference between pre- and postoperative values with a one-sided Wilcoxon signed-rank test, assuming a mean difference of 5, a standard deviation of 8 for both groups, and a 2.5% alpha. Additional subjects were recruited to ensure statistical significance in case of adverse events.

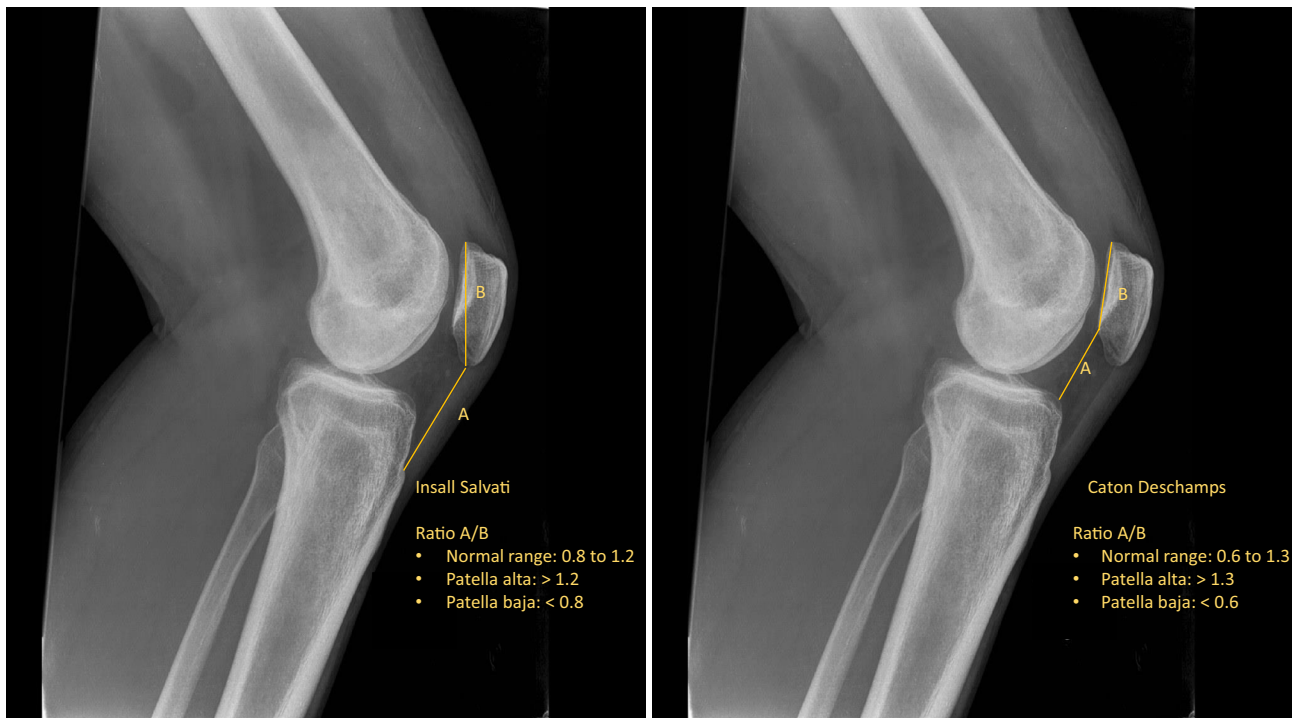


Fig. 1 Methods to evaluate the IS and CD on plain radiographs

## Statistical analysis

Statistical analyses were conducted in R version 4.1.1 (R Development Core Team, Austria) and SAS/STAT version 9.3 (SAS Institute Inc., Cary, NC, USA). Summary statistics are presented as mean and standard deviation for continuous data or absolute frequency and percentage for dichotomic data. A chi-square test for categorical variables and, for continuous variables, a *t*-test (for parametric statistics), or a Wilcoxon–Mann–Whitney test (for non-parametric statistics) was performed. To compare CD and IS, a *t*-test or a Wilcoxon signed ranks test was conducted based on score distribution. Subgroup analysis was performed to evaluate whether gender, age, and BMI are associated with differences in patellar height. Both in the intergroup and the subgroup analysis, age and BMI groups were defined dichotomizing the variable at its average rounded value, while pre-operative values of CD and IS above and below 1 were used to identify patients with low and high patellar position.

## Results

### Patient enrolment

228 patients were recruited. Of them, 5 patients ( $N=3$  anterior cruciate ligament reconstruction,  $N=2$  tibial osteotomy) were excluded as they had undergone previous surgery on

the knee. A further five patients declined to participate. 223 patients underwent surgery. 15 patients were lost at follow-up. This left 203 patients for inclusion: 119 patients were included in the medial UKA and 84 in the lateral cohort (Fig. 2).

### Patient demographic

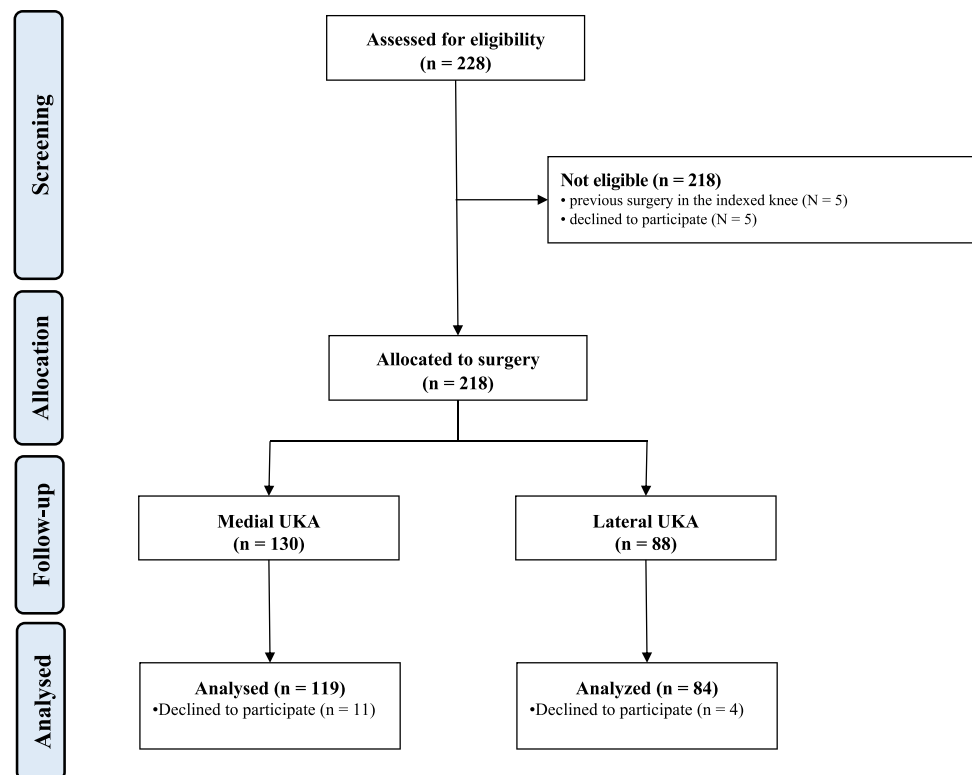
The mean age of the patients was  $68.9 \pm 6.7$  years and the mean BMI was  $28.1 \pm 4.1$  kg/m<sup>2</sup>. 54% (110 of 203 patients) were women. On admission, between-group comparability was found in age, BMI, sex, and length of the follow-up (Table 1).

### Results syntheses

No between- and within-group difference was detected pre- and post-operatively in the Insall–Salvati and Caton–Deschamps indices of patients who underwent medial and lateral UKA (Table 2).

### Subgroup analysis

No between- and within-group difference was detected pre- and post-operatively in all comparisons according to sex, age, and BMI (Table 3).

**Fig. 2** STROBE flow chart of patient enrolment**Table 1** Demographic data

Endpoint	Medial (N=119)	Lateral (N=84)	P
Age	69.69 ± 7.25	67.89 ± 5.77	0.07
BMI	27.91 ± 4.25	27.85 ± 3.96	0.9
Women	65 (54.6%)	45 (53.6%)	0.9
Follow-up (months)	26.9 ± 1.8	26.7 ± 1.7	0.4

**Table 2** Pre- and postoperative radiographic and clinical scores

	Medial (N=119)	Lateral (N=84)	P
CD pre-op	0.97 ± 0.15	0.98 ± 0.14	0.691
CD post-op	0.95 ± 0.14	0.99 ± 0.15	0.058
IS pre-op	1.05 ± 0.15	1.08 ± 0.14	0.129
IS post-op	1.04 ± 0.15	1.06 ± 0.13	0.547

IS, Insall–Salvati; CD, Caton–Deschamps

## Discussion

This study prospectively compared the patella height in patients who underwent medial versus lateral UKA. The prospective design might contribute to reduce the risk of selection bias, impacting the reliability of the results. According to the main findings of the present study, no difference was found in patella height between patients who

underwent medial compared to lateral UKA. Furthermore, there was no evidence of an association between patient characteristics (sex, age, BMI) and differences in patella height between the two implants. These results agree with previous investigations which found inconsistent results [8, 16, 44]. However, no superiority of medial versus lateral UKA survival was found in a previous systematic review with a follow-up of 15 years and a previous meta-analysis reporting the 10-year outcomes [8, 45]. Weale et al. [46] found no significant change in patellar height up to 5 years following UKA. These results might be explained by the resurfacing nature of the procedure and the limited bone cuts, and changes in patellar height after UKA are limited. Moreover, the minimally invasive incision and the avoidance of patellar eversion cause less trauma to Hoffa's fat pad and also prevent changes in patellar height [47].

UKA is a bone- and ligament-sparing option in patients with unicompartmental OA [7, 45]. Approximately 90% of all UKA procedures are performed at the medial and 10% at the lateral compartment [16, 17], which is attributable to a higher incidence of diseases, such as OA or osteonecrosis, at the medial compartment [8]. Compared to medial UKA, lateral UKA is considered more challenging given the anatomic and kinematic differences between the two compartments [17, 48]: in contrast to the medial femoral condyle, the lateral condyle shows backwards rolling and sliding during flexion [48, 49]. Furthermore, implant design factors and the lower surgical volume in lateral compared to medial UKA

**Table 3** Subgroup analysis between medial and lateral UKA divided for gender, age, and BMI

	Medial <i>N</i> =45	Lateral <i>N</i> =65	<i>P</i>
<b>Women</b>			
CD pre-op	0.97 ± 0.15	0.99 ± 0.14	0.6
CD post-op	1.01 ± 0.17	0.97 ± 0.14	0.3
IS pre-op	1.10 ± 0.14	1.06 ± 0.15	0.08
IS post-op	1.07 ± 0.13	1.06 ± 0.13	0.9
<b>Men</b>			
CD pre-op	0.98 ± 0.13	0.95 ± 0.16	0.4
CD post-op	0.97 ± 0.13	0.93 ± 0.14	0.1
IS pre-op	1.06 ± 0.15	1.03 ± 0.15	0.7
IS post-op	1.05 ± 0.14	1.02 ± 0.16	0.3
<b>Age &lt; 70 years</b>			
CD pre-op	0.99 ± 0.15	0.97 ± 0.16	0.5
CD post-op	0.99 ± 0.15	0.97 ± 0.16	0.5
IS pre-op	1.08 ± 0.13	1.04 ± 0.17	0.7
IS post-op	1.06 ± 0.13	1.03 ± 0.16	0.7
<b>Age ≥ 70 years</b>			
CD pre-op	0.96 ± 0.13	0.97 ± 0.14	0.5
CD post-op	0.99 ± 0.16	0.94 ± 0.13	0.1
IS pre-op	1.08 ± 0.16	1.05 ± 0.13	0.1
IS post-op	1.06 ± 0.14	1.05 ± 0.14	0.8
<b>BMI &lt; 28</b>			
CD pre-op	0.96 ± 0.11	0.96 ± 0.16	0.7
CD post-op	0.96 ± 0.15	0.95 ± 0.13	0.8
IS pre-op	1.08 ± 0.17	1.04 ± 0.15	0.6
IS post-op	1.05 ± 0.15	1.05 ± 0.14	0.9
<b>BMI ≥ 28</b>			
CD pre-op	1.00 ± 0.16	0.98 ± 0.13	0.5
CD post-op	1.03 ± 0.15	0.96 ± 0.16	0.06
IS pre-op	1.09 ± 0.11	1.05 ± 0.15	0.09
IS post-op	1.07 ± 0.11	1.04 ± 0.16	0.3

IS, Insall–Salvati; CD, Caton–Deschamps

might contribute to the higher technical complexity in lateral UKA [17, 50]. In addition, the patella tracks more laterally during high flexion, possibly causing patellar impingement [17]. The patellar height affects the knee biomechanics and patellofemoral function [51–53]. Recently, the importance of patellar height following knee surgery, especially TKA, has been discussed [22, 54]. Both IS and CD are validated and well-known methods to evaluate patellar height [55–57]. Different methods to measure patellar height have been developed over time [33, 58, 59]. Verhulst et al. [38] found that the IS ratio but not the CD ratio was associated with a high intra- and inter-observer reliability. In contrast, good intra- and inter-observer reliability for both the IS and the CD ratio was found in other studies [60, 61].

Postoperative patella baja refers to a decreased patellar height and might occur following the shortening of the patellar tendon due to scar formation and contracture, and pseudo-patella baja happens in joint line elevation [62]. Joint line elevation possibly results in a reduction of the extensor mechanism power and a reduced knee flexion due to a tightening of the collateral ligaments and reduced femoral rollback [63]. Moreover, joint line elevation was associated with anterior knee pain, patellofemoral problems, reduced knee flexion capability, and midflexion joint instability in previous studies [63–65]. Patella baja following TKA has been investigated in numerous studies, while its occurrence in patients undergoing UKA is still unclear to date [47].

## Conclusion

No difference was found in patella height between patients who underwent medial compared to lateral UKA. No evidence of an association between patient characteristics (sex, age, BMI) and patella height between the two implants was found.

**Author contributions** RDA contributed to conceptualisation, writing, supervision, and revision; FR, CU, IM, NU, and MF performed supervision and revision; JP and FM were involved in writing. All the authors have agreed to the final version to be published and agree to be accountable for all aspects of the work.

**Funding** Open Access funding enabled and organized by Projekt DEAL.

**Availability of data and materials** All data and materials are available on reasonable request to Dr. Riccardo D'Ambrosi (riccardo.dambrosi@hotmail.it).

## Declarations

**Conflict of interest** All authors declare that they have no conflict of interest.

**Consent for publication** Not applicable.

**Ethics approval and consent to participate** The present study was approved by the Ethic Committee of the University of Milan, Italy (CE 236/2017). Signed informed consent was obtained from all participants. All the procedures involving human participants were performed in compliance with the 1964 Helsinki Declaration and its later amendments.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

## References


- Migliorini F, Tingart M, Niewiera M, Rath B, Eschweiler J (2019) Unicompartmental versus total knee arthroplasty for knee osteoarthritis. *Eur J Orthop Surg Traumatol* 29(4):947–955. <https://doi.org/10.1007/s00590-018-2358-9>
- Migliorini F, Aretini P, Driessen A, El Mansy Y, Quack V, Tingart M, Eschweiler J (2020) Better outcomes after mini-subvastus approach for primary total knee arthroplasty: a Bayesian network meta-analysis. *Eur J Orthop Surg Traumatol* 30(6):979–992. <https://doi.org/10.1007/s00590-020-02648-9>
- Migliorini F, Pintore A, Cipollaro L, Oliva F, Maffulli N (2021) Outpatient total knee arthroplasty: a meta-analysis. *App Sci* 11(20):9376. <https://doi.org/10.3390/app11209376>
- Skolnick MD, Bryan RS, Peterson LF (1975) Unicompartmental polycentric knee arthroplasty: description and preliminary results. *Clin Orthop Relat Res* 112:208–214
- Tamashiro KK, Morikawa L, Andrews S, Nakasone CK (2023) Can single-stage bilateral unicompartmental knee arthroplasty be safely performed in patients over 70? *J Orthop* 37:41–45. <https://doi.org/10.1016/j.jor.2023.02.005>
- Xi G, Wang HH, Li H, Zhang M (2022) Short-term outcomes of Oxford unicompartmental knee arthroplasty with coronal subluxation of the knee: a retrospective case-control study. *J Orthop Traumatol* 23(1):6. <https://doi.org/10.1186/s10195-022-00626-x>
- Fiocchi A, Condello V, Madonna V, Bonomo M, Zorzi C (2017) Medial vs. lateral unicompartmental knee arthroplasty: clinical results. *Acta Biomed* 88(2s):38–44. <https://doi.org/10.23750/abm.v88i2-S.6510>
- Han SB, Lee SS, Kim KH, Im JT, Park PS, Shin YS (2020) Survival of medial versus lateral unicompartmental knee arthroplasty: a meta-analysis. *PLoS ONE* 15(1):e0228150. <https://doi.org/10.1371/journal.pone.0228150>
- Naal FD, Neuerburg C, von Knoch F, Salzmann GM, Kriner M, Munzinger U (2009) Patellar height before and after unicompartmental knee arthroplasty: Association with early clinical outcome? *Arch Orthop Trauma Surg* 129(4):541–547. <https://doi.org/10.1007/s00402-008-0654-2>
- Migliorini F, Maffulli N, Cuozzo F, Elsner K, Hildebrand F, Eschweiler J, Driessen A (2022) Mobile bearing versus fixed bearing for unicompartmental arthroplasty in monocompartmental osteoarthritis of the knee: a meta-analysis. *J Clin Med* 11(10):1. <https://doi.org/10.3390/jcm11102837>
- Migliorini F, Driessen A, Oliva F, Maffulli GD, Tingart M, Maffulli N (2020) Better outcomes and reduced failures for arthroplasty over osteotomy for advanced compartmental knee osteoarthritis in patients older than 50 years. *J Orthop Surg Res* 15(1):545. <https://doi.org/10.1186/s13018-020-02079-6>
- Barbera JP, Xiao RC, Williams CS, Poeran J, Moucha CS, Chen DD, Hayden BL (2022) Treatment patterns and failure rates associated with prosthetic joint infection in unicompartmental knee arthroplasty: a systematic review. *J Orthop* 34:288–294. <https://doi.org/10.1016/j.jor.2022.09.008>
- Yadav AK, Parihar M, Mariani I, Giorgino R, Mangiavini L, Ursino N, D'Ambrosi R (2022) High tibial osteotomy with an external fixator or unicompartmental knee arthroplasty for varus knee in young patients? *J Orthop* 34:254–259. <https://doi.org/10.1016/j.jor.2022.09.006>
- Liddle AD, Judge A, Pandit H, Murray DW (2014) Adverse outcomes after total and unicompartmental knee replacement in 101,330 matched patients: a study of data from the National Joint Registry for England and Wales. *Lancet* 384(9952):1437–1445. [https://doi.org/10.1016/s0140-6736\(14\)60419-0](https://doi.org/10.1016/s0140-6736(14)60419-0)
- Zhou X, Sun C, Xu R, Zhang X, Yu X (2023) The effect of tibial component rotational alignment on clinical outcomes of mobile-bearing unicompartmental knee arthroplasty. *J Orthop Surg Res* 18(1):217. <https://doi.org/10.1186/s13018-023-03707-7>
- Baker PN, Jameson SS, Deehan DJ, Gregg PJ, Porter M, Tucker K (2012) Mid-term equivalent survival of medial and lateral unicompartmental knee replacement: an analysis of data from a National Joint Registry. *J Bone Joint Surg Br* 94(12):1641–1648. <https://doi.org/10.1302/0301-620x.94b12.29416>
- Scott RD (2005) Lateral unicompartmental replacement: a road less traveled. *Orthopedics* 28(9):983–984. <https://doi.org/10.3928/0147-7447-20050901-34>
- Asadollahi S, Wilson HA, Thomson FR, Vaz K, Middleton R, Jenkins C, Alvand A, Bottomley N, Dodd CA, Price AJ, Murray

- DW, Jackson WF (2022) Early results of fixed-bearing unicompartmental knee replacement designed for the lateral compartment. *J Orthop Surg Res* 17(1):146. <https://doi.org/10.1186/s13018-021-02896-3>
19. Xu K, Chen Q, Yan Q, Wang Q, Sun J (2022) Comparison of computer-assisted navigated technology and conventional technology in unicompartmental knee arthroplasty: a meta-analysis. *J Orthop Surg Res* 17(1):123. <https://doi.org/10.1186/s13018-022-03013-8>
  20. Itou J, Kuwashima U, Itoh M, Okazaki K (2022) Perioperative varus alignment does not affect short-term patient-reported outcome measures following mobile-bearing unicompartmental knee arthroplasty. *J Orthop Surg Res* 17(1):98. <https://doi.org/10.1186/s13018-022-02999-5>
  21. Pandit H, Jenkins C, Gill HS, Smith G, Price AJ, Dodd CA, Murray DW (2011) Unnecessary contraindications for mobile-bearing unicompartmental knee replacement. *J Bone Joint Surg Br* 93(5):622–628. <https://doi.org/10.1302/0301-620x.93b5.26214>
  22. Caton JH, Prudhon JL, Aslanian T, Verdier R (2016) Patellar height assessment in total knee arthroplasty: a new method. *Int Orthop* 40(12):2527–2531. <https://doi.org/10.1007/s00264-016-3256-6>
  23. Matz J, Lanting BA, Howard JL (2019) Understanding the patellofemoral joint in total knee arthroplasty. *Can J Surg* 62(1):57–65. <https://doi.org/10.1503/cjs.001617>
  24. Leiss F, Götz JS, Maderbacher G, Zeman F, Meissner W, Grifka J, Benditz A, Greimel F (2020) Pain management of unicompartmental (UKA) vs. total knee arthroplasty (TKA) based on a matched pair analysis of 4144 cases. *Sci Rep* 10(1):17660. <https://doi.org/10.1038/s41598-020-74986-x>
  25. Cross MB, Nam D, Plaskos C, Sherman SL, Lyman S, Pearle AD, Mayman DJ (2012) Recutting the distal femur to increase maximal knee extension during TKA causes coronal plane laxity in mid-flexion. *Knee* 19(6):875–879. <https://doi.org/10.1016/j.knee.2012.05.007>
  26. Salem KH, Sheth MR (2021) Variables affecting patellar height in patients undergoing primary total knee replacement. *Int Orthop* 45(6):1477–1482. <https://doi.org/10.1007/s00264-020-04890-6>
  27. Jenny JY (2018) Minimally invasive unicompartmental knee arthroplasty. *Eur J Orthop Surg Traumatol* 28(5):793–797. <https://doi.org/10.1007/s00590-017-2107-5>
  28. Gwyn R, Kotwal RS, Holt MD, Davies AP (2016) Complete excision of the infrapatellar fat pad is associated with patellar tendon shortening after primary total knee arthroplasty. *Eur J Orthop Surg Traumatol* 26(5):545–549. <https://doi.org/10.1007/s00590-016-1775-x>
  29. Nisar S, Lamb JN, Somashekar N, Pandit H, van Duren BH (2019) Preservation vs. resection of the infrapatellar fat pad during total knee arthroplasty part II: a systematic review of published evidence. *Knee* 26(2):422–426. <https://doi.org/10.1016/j.knee.2019.01.007>
  30. Sun C, Zhang X, Lee WG, Tu Y, Li H, Cai X, Yang H (2020) Infrapatellar fat pad resection or preservation during total knee arthroplasty: a meta-analysis of randomized controlled trials. *J Orthop Surg Res* 15(1):297. <https://doi.org/10.1186/s13018-020-01823-2>
  31. Zhang G, Smith BP, Plate JF, Casanova R, Hsu FC, Li J, Xia L, Li KC, Poehling GG, Zhou X (2016) A systematic approach to predicting the risk of unicompartmental knee arthroplasty revision. *Osteoarth Cartil* 24(6):991–999. <https://doi.org/10.1016/j.joca.2016.01.004>
  32. Pang HN, Yeo SJ, Chong HC, Chin PL, Chia SL, Lo NN (2013) Joint line changes and outcomes in constrained versus unconstrained total knee arthroplasty for the type II valgus knee. *Knee Surg Sports Traumatol Arthrosc* 21(10):2363–2369. <https://doi.org/10.1007/s00167-013-2390-6>
  33. D'Ambrosi R, Buda M, Nuara A, Mariani I, Scelsi M, Valli F, Ursino N, Hirschmann MT (2022) Patellar height after unicompartmental knee arthroplasty: comparison between fixed and mobile bearing. *Arch Orthop Trauma Surg* 142(11):3449–3460. <https://doi.org/10.1007/s00402-021-04183-6>
  34. Cuschieri S (2019) The STROBE guidelines. *Saudi J Anaesth* 13(Suppl 1):S31–S34. [https://doi.org/10.4103/sja.SJA\\_543\\_18](https://doi.org/10.4103/sja.SJA_543_18)
  35. Kohn MD, Sassoon AA, Fernando ND (2016) Classifications in brief: Kellgren–Lawrence classification of osteoarthritis. *Clin Orthop Relat Res* 474(8):1886–1893. <https://doi.org/10.1007/s11999-016-4732-4>
  36. De Berardinis L, Senarighi M, Ciccullo C, Forte F, Spezia M, Gigante AP (2022) Fast-track surgery and telerehabilitation protocol in unicompartmental knee arthroplasty leads to superior outcomes when compared with the standard protocol: a propensity-matched pilot study. *Knee Surg Relat Res* 34(1):44. <https://doi.org/10.1186/s43019-022-00173-z>
  37. Konrads C, Grosse LC, Ahmad SS, Springer F, Schreiner AJ, Schmidutz F, Erne F (2021) Reliability of a Caton–Deschamps-derived patella height index for knee arthroplasty. *Int Orthop* 45(8):2001–2005. <https://doi.org/10.1007/s00264-020-04931-0>
  38. Verhulst FV, van Sambeeck JDP, Olthuis GS, van der Ree J, Koëter S (2020) Patellar height measurements: Insall–Salvati ratio is most reliable method. *Knee Surg Sports Traumatol Arthrosc* 28(3):869–875. <https://doi.org/10.1007/s00167-019-05531-1>
  39. Insall J, Salvati E (1971) Patella position in the normal knee joint. *Radiology* 101(1):101–104. <https://doi.org/10.1148/101.1.101>
  40. Caton J, Deschamps G, Chambat P, Lerat JL, Dejour H (1982) Patella infera. Apropos of 128 cases. *Rev Chir Orthop Reparatrice Appar Mot* 68(5):317–325
  41. Migliorini F, Eschweiler J, Betsch M, Knobe M, Tingart M, Maffulli N (2022) Prognostic factors for isolated medial patellofemoral ligament reconstruction: a systematic review. *Surgeon* 20(4):e112–e121. <https://doi.org/10.1016/j.surge.2021.03.003>
  42. Migliorini F, Oliva F, Maffulli GD, Eschweiler J, Knobe M, Tingart M, Maffulli N (2021) Isolated medial patellofemoral ligament reconstruction for recurrent patellofemoral instability: analysis of outcomes and risk factors. *J Orthop Surg Res* 16(1):239. <https://doi.org/10.1186/s13018-021-02383-9>
  43. Migliorini MF, Pilone M, Eschweiler J, Marsilio E, Hildebrand F, Maffulli N (2022) High rates of damage to the medial patellofemoral ligament lateral trochlea and patellar crest after acute patellar dislocation: MRI analysis. *Arthroscopy* 1:1. <https://doi.org/10.1016/j.arthro.2022.01.044>
  44. John J, Mauffrey C, May P (2011) Unicompartmental knee replacements with Miller–Galante prosthesis: two to 16-year follow-up of a single surgeon series. *Int Orthop* 35(4):507–513. <https://doi.org/10.1007/s00264-010-1006-8>
  45. van der List JP, McDonald LS, Pearle AD (2015) Systematic review of medial versus lateral survivorship in unicompartmental knee arthroplasty. *Knee* 22(6):454–460. <https://doi.org/10.1016/j.knee.2015.09.011>
  46. Weale AE, Murray DW, Newman JH, Ackroyd CE (1999) The length of the patellar tendon after unicompartmental and total knee replacement. *J Bone Joint Surg Br* 81(5):790–795. <https://doi.org/10.1302/0301-620x.81b5.9590>
  47. Neogi DS, Bae JH, Seok CW, Lim HC (2014) Impact of patellar height on unicompartment knee arthroplasty: Does patella baja lead to an inferior outcome? *J Orthop Traumatol* 15(1):47–54. <https://doi.org/10.1007/s10195-013-0268-5>
  48. Hill PF, VEDI V, Williams A, Iwaki H, Pinskerova V, Freeman MA (2000) Tibiofemoral movement 2: the loaded and unloaded living knee studied by MRI. *J Bone Joint Surg Br* 82(8):1196–1198. <https://doi.org/10.1302/0301-620x.82b8.10716>

49. Iwaki H, Pinskerova V, Freeman MA (2000) Tibiofemoral movement 1: the shapes and relative movements of the femur and tibia in the unloaded cadaver knee. *J Bone Joint Surg Br* 82(8):1189–1195. <https://doi.org/10.1302/0301-620x.82b8.10717>
50. Ollivier M, Abdel MP, Parratte S, Argenson JN (2014) Lateral unicondylar knee arthroplasty (UKA): contemporary indications, surgical technique, and results. *Int Orthop* 38(2):449–455. <https://doi.org/10.1007/s00264-013-2222-9>
51. Amis A, Farahmand F (1996) Extensor mechanism of the knee. *Curr Orthop* 10(2):102–109
52. Lum ZC, Saiz AM, Pereira GC, Meehan JP (2020) Patella Baja in total knee arthroplasty. *J Am Acad Orthop Surg* 28(8):316–323. <https://doi.org/10.5435/JAAOS-D-19-00422>
53. Konrads C, Rejaibia J, Grosse LC, Springer F, Schreiner AJ, Schmidutz F, Erne F (2021) Patella-height analysis and correlation with clinical outcome after primary total knee arthroplasty. *J Orthop* 23:169–174. <https://doi.org/10.1016/j.jor.2021.01.001>
54. Portner O (2014) High tibial valgus osteotomy: closing, opening or combined? Patellar height as a determining factor. *Clin Orthop Relat Res* 472(11):3432–3440. <https://doi.org/10.1007/s11999-014-3821-5>
55. Ishii Y, Noguchi H, Sato J, Ishii H, Ezawa N, Toyabe SI (2019) Insall–Salvati ratio stabilizes one year after mobile-bearing total knee arthroplasty and does not correlate with mid-to-long-term clinical outcomes. *Knee Surg Sports Traumatol Arthrosc* 27(5):1604–1610. <https://doi.org/10.1007/s00167-018-5211-0>
56. Meneghini RM, Ritter MA, Pierson JL, Meding JB, Berend ME, Faris PM (2006) The effect of the Insall–Salvati ratio on outcome after total knee arthroplasty. *J Arthroplasty* 21(6 Suppl 2):116–120. <https://doi.org/10.1016/j.arth.2006.04.014>
57. Prudhon JL, Caton JH, Aslanian T, Verdier R (2018) How is patella height modified after total knee arthroplasty? *Int Orthop* 42(2):311–316. <https://doi.org/10.1007/s00264-017-3539-6>
58. Gaillard R, Bankhead C, Budhiparama N, Batailler C, Servien E, Lustig S (2019) Influence of patella height on total knee arthroplasty: outcomes and survival. *J Arthroplasty* 34(3):469–477. <https://doi.org/10.1016/j.arth.2018.10.037>
59. Schreiner AJ, Spiegel L, Yan SG, Konrads C, Erne F, Hemmann P, Schmidutz F (2023) Evaluation of modified and newly applied patella height indices in primary total knee arthroplasty. *Skeletal Radiol* 52(1):73–82. <https://doi.org/10.1007/s00256-022-04142-1>
60. Barnett AJ, Prentice M, Mandalia V, Wakeley CJ, Eldridge JD (2009) Patellar height measurement in trochlear dysplasia. *Knee Surg Sports Traumatol Arthrosc* 17(12):1412–1415. <https://doi.org/10.1007/s00167-009-0801-5>
61. Munch JL, Sullivan JP, Nguyen JT, Mintz D, Green DW, Shubin Stein BE, Strickland S (2016) Patellar articular overlap on MRI is a simple alternative to conventional measurements of patellar height. *Orthop J Sports Med* 4(7):2325967116656328. <https://doi.org/10.1177/2325967116656328>
62. Chonko DJ, Lombardi AV Jr, Berend KR (2004) Patella Baja and total knee arthroplasty (TKA): etiology, diagnosis, and management. *Surg Technol Int* 12:231–238
63. Kazemi SM, Daftari Besheli L, Ejazi A, Miniator Sajadi MR, Okhovatpoor MA, Farhang Zanganeh R, Minaei R (2011) Pseudo-patella Baja after total knee arthroplasty. *Med Sci Monit* 17(5):Cr292-296. <https://doi.org/10.12659/msm.881770>
64. Porteous AJ, Hassaballa MA, Newman JH (2008) Does the joint line matter in revision total knee replacement? *J Bone Joint Surg Br* 90(7):879–884. <https://doi.org/10.1302/0301-620x.90b7.20566>
65. Martin JW, Whiteside LA (1990) The influence of joint line position on knee stability after condylar knee arthroplasty. *Clin Orthop Relat Res* 259:146–156

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

## Authors and Affiliations

Riccardo D'Ambrosi<sup>1,2</sup> · Francesco Rubino<sup>3,5</sup> · Chiara Ursino<sup>3,5</sup> · Ilaria Mariani<sup>4</sup> · Nicola Ursino<sup>1</sup> · Matteo Formica<sup>3,5</sup> · Julia Prinz<sup>6</sup> · Filippo Migliorini<sup>7,8</sup> 

✉ Filippo Migliorini  
migliorini.md@gmail.com

Riccardo D'Ambrosi  
riccardo.dambrosi@hotmail.it

Francesco Rubino  
f.r1997@libero.it

Chiara Ursino  
ursino.chiara@hotmail.it

Ilaria Mariani  
ilaria.mariani1618@gmail.com

Nicola Ursino  
nicolaursino@libero.it

Matteo Formica  
matteo.formica@unige.it

Julia Prinz  
juprinz@ukaachen.de

- 1 IRCCS Ospedale Galeazzi Sant'Ambrogio, Milan, Italy
- 2 Dipartimento di Scienze Biomediche per la Salute, Università degli Studi di Milano, Milan, Italy
- 3 Orthopaedic Clinic, IRCCS Hospital Policlinico San Martino, Genoa, Italy
- 4 Institute for Maternal and Child Health IRCCS Burlo Garofolo, Trieste, Italy
- 5 DISC - Department of Surgical Sciences and Integrated Diagnostics, University of Genoa, Genoa, Italy
- 6 Department of Ophthalmology, RWTH University Hospital, 52074 Aachen, Germany
- 7 Department of Orthopaedic, Trauma, and Reconstructive Surgery, RWTH University Hospital, Pauwelsstraße 30, 52074 Aachen, Germany
- 8 Department of Orthopaedics and Trauma Surgery, Academic Hospital of Bolzano (SABES-ASDAA), Teaching Hospital of the Paracelsus Medical University, 39100 Bolzano, Italy