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Medial unicompartmental knee arthroplasty improves congruence and restores joint space width of the lateral compartment

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ABSTRACT

Background: Osteoarthritic progression of the lateral compartment remains a leading indication for medial unicompartmental knee arthroplasty (UKA) revision. Therefore, the purpose of this study was to evaluate the alterations of the lateral compartment congruence and joint space width (JSW) following medial UKA.

Methods: Retrospectively, lateral compartment congruence and JSW were evaluated in 174 knees (74 females, 85 males, mean age 65.5 years; SD ± 10.1) preoperatively and six weeks postoperatively, and compared to 41 healthy knees (26 men, 15 women, mean age 33.7 years; SD ± 6.4). Congruence (CI) was calculated using validated software that evaluates the geometric relationship between surfaces and calculates a congruence index (CI). JSW was measured on three sides (inner, middle, outer) by subdividing the lateral compartment into four quarters.

Results: The CI of the control group was 0.98 (SD ± 0.01). The preoperative CI was 0.88 (SD ± 0.01), which improved significantly to 0.93 (SD ± 0.03) postoperatively ($p < 0.001$). In 82% of knees, CI improved after surgery, while in 18% it decreased. The preoperative significant JSW differences of the inner ($p < 0.001$) and outer JSW ($p < 0.001$) were absent postoperatively.

Conclusion: Our data suggests that a well-conducted medial UKA not only resurfaces the medial compartment but also improves congruence and restores the JSW of the lateral compartment.

1. Introduction

Medial unicompartmental knee arthroplasty (UKA) is a well-accepted surgical treatment for end-stage osteoarthritis (OA) that is located to the medial compartment of the knee. Multiple studies report survival rates of >90–95% at 10 years with good to excellent subjective outcome results [1–5]. Evaluating the various modes of implant failure, osteoarthritic progression of the lateral compartment is one of the dominant reasons for revision surgery [2]. Therefore, optimal cartilage viability of the lateral compartment is essential for medial UKA survival.

Chronic uneven load transmission across the knee is present in OA and plays an important role in the presence and progression of the disease. Lower limb alignment and coronal tibiofemoral subluxation are two important mechanical factors that can influence load distribution over the articular cartilage of the knee [6–8]. Both influence the congruity, leading to an altered distribution of transmitted forces over the affected joint. In the osteoarthritic knee, some regions of the articular cartilage encounter increased peak loads, whereas the forces that are transmitted are reduced in other regions [9,10]. This chronic altered distribution of forces has a well-recognized influence on cartilage viability [9,11]. Since congruence plays a central role in the equal distribution of forces over a joint, tibiofemoral joint incongruence can therefore cause progressive OA.

The routine method to evaluate progressive degenerative changes of the knee is to measure the joint space width (JSW) on weight-bearing radiographs. Recent studies have proven that the JSW measurement is highly associated with the volume and compression of cartilage and meniscal extrusion [12,13]. Therefore, it is considered as a reliable method to evaluate degenerative progression over time. The ease of measuring the JSW, have led that the method has become a frequently used method in the daily orthopedic practice to evaluate osteoarthritic progression.

Since degenerative progression of the lateral compartment remains a dominant reason for revision surgery, it is critically important to evaluate the alterations of the lateral compartment following medial UKA. A better understanding of the indirect changes following medial UKA will help us to optimize the results of the implant. In a recent study, congruence and joint space width alterations of the medial compartment were evaluated following lateral UKA [14]. The study concluded that lateral UKA not only resurfaces the lateral compartment but also improves

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medial compartment congruence and restores the JSW. However, since the medial and lateral compartments of the knee differ considerably [15–17], it is inaccurate and can be misleading to draw conclusions from the literature based on lateral UKAs when studying results about medial UKAs. Therefore, the purpose of this present study is to evaluate the congruence and joint space width alterations of the lateral compartment of the knee following a medial UKA. Our hypothesis is that implantation of a medial UKA will improve the congruence of the lateral compartment and restore JSW.

2. Methods and materials

This study is a retrospective review of an IRB-approved surgical database of the senior author. All patients who underwent UKA for isolated medial compartment osteoarthritis by the senior author between January 1, 2008, and June 30, 2011, were included for review. Indications for performing a UKA were the presence of isolated, medial compartment osteoarthritis, a flexion contracture of less than 10°, flexion to greater than 90°, and an intact anterior cruciate ligament based on clinical and intra-operative assessments. Furthermore, the varus deformity had to be passively correctable. Contraindications for performing a UKA were the presence of an inflammatory arthropathy, Kellgren–Lawrence grade 3–4 changes in the lateral compartment and suspected pain originating from the patellofemoral compartment on preoperative clinical examination. Inclusion criteria for this study were patients who received a UKA for isolated medial compartment OA. Patients without radiographs of adequate quality were excluded. This resulted in an exclusion of 102 patients (116 knees) that had undergone medial UKA. Of the included patients, electronic medical records and charts were reviewed for demographic data.

2.1. Surgical procedure

All surgery was performed by the senior author using a previously described, robotic-arm assisted technique for the preparation of both the femoral and tibial surfaces (MAKO Surgical Corp., Ft. Lauderdale, FL) [18,19]. Briefly, a preoperative plan was created from a three-dimensional (3-D) reconstruction of a computed tomography scan of the patient's hip, knee, and ankle, and computer-assisted design (CAD) models of the implanted components are positioned on 3-D models of the femur and tibia. Standard surgical navigation markers were placed in the femur and tibia, and also mounted on the robotic arm. Virtual modeling of the patient's knee and intra-operative long leg alignment tracking allowed real-time adjustments to target specific long leg alignment parameters and soft tissue balance. For the medial UKAs, the superficial and deep medial collateral ligaments were preserved and implant position (and thus, the bony resections) were planned to maintain tension of the MCL throughout the range of motion. In accordance with the guidelines set forth by Hernigou and Deschamps, the goal was an "undercorrection" of the varus deformities (an overall varus hip–knee–ankle alignment postoperatively), with avoidance of "overcorrection" and potentially hastened wear in the contralateral compartment [20]. The end of the robotic arm was equipped with a burr that was used to resect the bone. While inside the volume of bone to be resected, the robotic arm was operated without offering any resistance. As the burr approached the boundary, the robotic arm resisted that surgeon motion and kept the burr only within the accepted volume. Thus, the robotic arm effectively acted as a three-dimensional virtual instrument allowing precise execution of the preoperative plan [18].

2.2. Radiographical evaluation

As part of routine follow-up, patients underwent radiographic examination preoperatively and six weeks postoperatively. The radiographic evaluation consisted of standard weight-bearing antero-posterior (AP) radiographs of the knee, tunnel view radiographs and hip-to-ankle radiographs. A flexion-board of 40° was used for the tunnel view radiographs to control the flexion angle. Care was taken when obtaining the knee-to-hip radiographs to ensure that each patient stood with their patellae facing forwards in order to minimize rotational variation among the radiographs.

2.3. Congruence

The degree of articular congruence was calculated using a specially developed Iterative Closest Point (ICP) based software code (MATLAB, MathWorks Inc., Natick, MA, 2012). The ICP algorithm seeks to minimize the sum of the square distances between two clouds of points, and attempts to find the rigid transformation (translation and rotation)

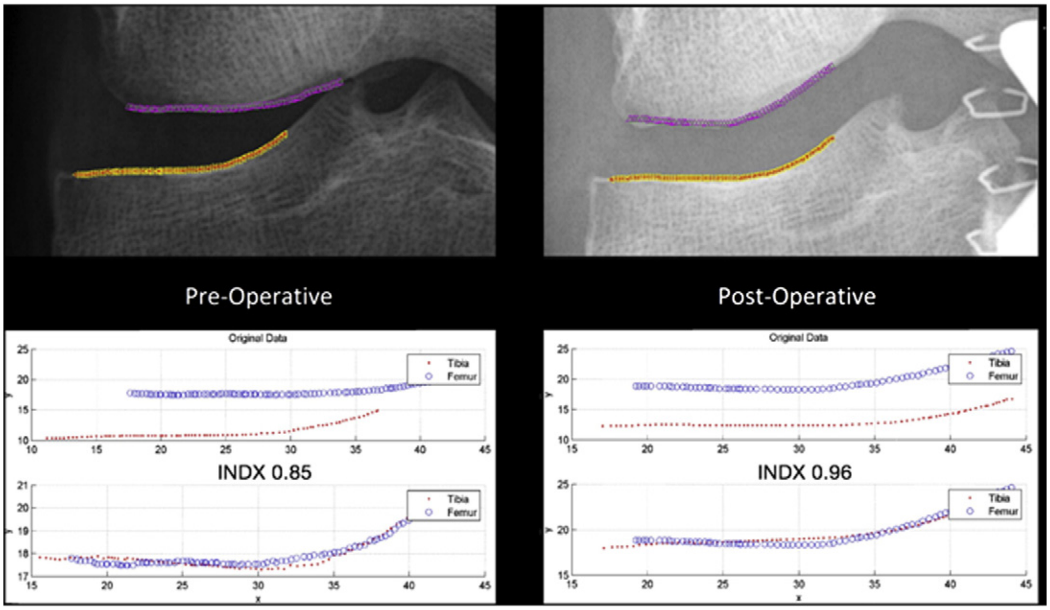

Figure 1. The performed iterative closest point algorithm calculates the congruence index (noted as INDX in the figure) of the lateral compartment pre- and postoperatively following manual digitization of the femoral and tibial surfaces.

that best aligns these two clouds. In our code, the two clouds of points represent the digitized femoral and tibial articular surfaces of the lateral compartment of the knee (Figure. 1). By measuring the translation and rotation needed for the articular surfaces to be fully congruent, the code calculates the degree of congruence of the lateral compartment and presents it as a Congruence Index (CI). A CI with a value of one indicates complete geometric congruence where load is presumably transmitted ideally from the femoral to the tibial articular surfaces. A value of 0 indicates a 100% dislocation of the articular surfaces. This method has been validated in a cadaveric model and used in our previous work [14,21]. The CI was measured by two independent observers on both the preoperative and postoperative weight-bearing tunnel view radiographs. Patients were divided into two groups. Group A included knees with increased CI after medial UKA implantation and group B included knees with decreased CI after medial UKA.

2.4. Joint space width

JSW was measured according to a validated [22] method, by dividing the lateral compartment (i.e. inner, middle, outer) into four quarters (Figure 2) on the tunnel view weight-bearing radiographs. The tibiofemoral inter-bone distance was measured in millimeters on weight-bearing tunnel radiographs preoperatively, postoperatively and in the control group. For evaluation of knee compartment congruence and joint space width in the normal healthy group, we used weight-bearing tunnel view radiographs of both lower extremities of patients younger than 40 years who underwent anterior cruciate ligament reconstructions or complained about anterior knee pain and had no complaints in the contralateral knee. The CI and JSW were both measured in the contralateral "normal" knees using our specially developed code and considered as normal control value.

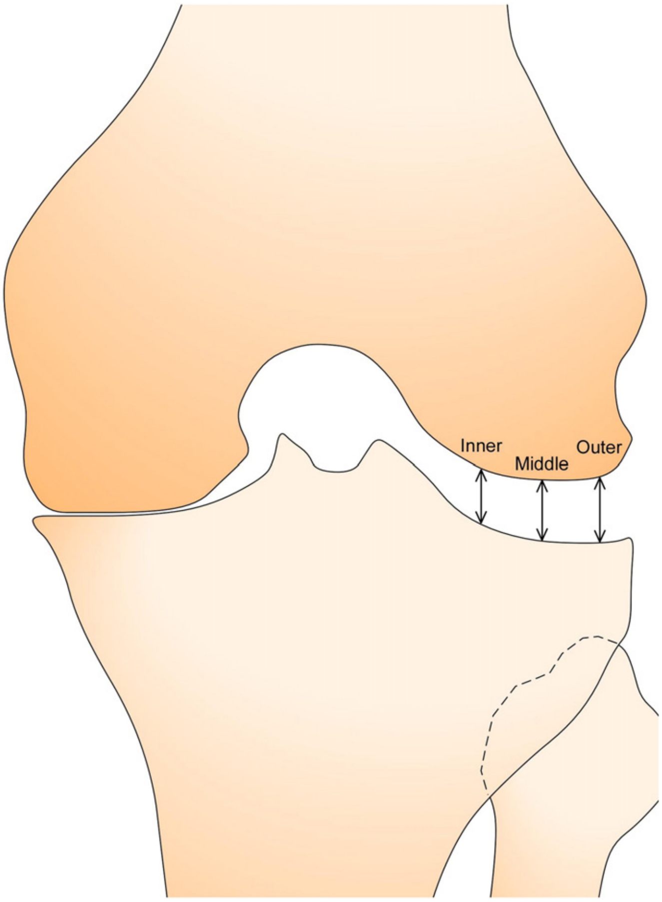

Figure 2. The three measured JSW sides of the lateral compartment in millimeters.

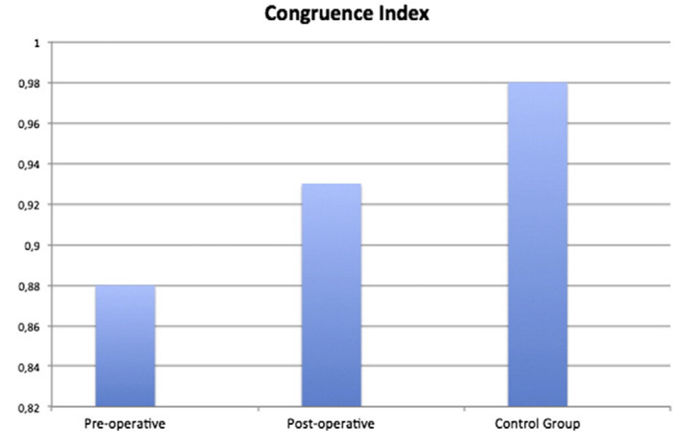

Figure 3. Congruence Index of the lateral compartment preoperatively (0.88 ± 0.01), postoperatively (0.93 ± 0.03) and in control group (0.98 ± 0.01). The preoperative lateral compartment CI improved significantly following medial UKA ($p < 0.001$). However, the postoperative CI difference with the lateral compartment CI of the control group remained significantly ($p = 0.01$).

2.5. Mechanical axis alignment

Preoperatively and six weeks postoperatively, the mechanical axis alignment of the lower extremity was measured on the AP hip-to-ankle radiographs. The femoral mechanical axis was formed by drawing a line from the center of the femoral head to the center of the center of the femoral notch. Subsequently, a line was drawn from the tibial spine toward to center of the tibial plafond, which formed the tibial mechanical axis. The angle formed between the two lines forms the mechanical alignment.

2.6. Preoperative degenerative state of the lateral compartment

The preoperative degenerative changes of the lateral compartment were recorded with use of the KL scores.

2.7. Statistical analysis

Interclass correlation coefficients (ICC) were calculated to evaluate inter-observer reliability for CI and JSW measurements. The ICCs were graded using previously described semi-quantitative criteria: excellent for $0.9 \le p \le 1.0$, good for $0.7 \le p \le 0.89$, fair/moderate for $0.5 \le p \le 0.69$, low for $0.25 \le p \le 0.49$, and poor for $0.0 \le p \le 0.24$ [23]. Student's paired *t*-tests were used to detect a difference between the preoperative and postoperative congruence index and between the groups with increased and decreased CIs. Chi square test was used to evaluate relationship between gender and changes in CI after surgery. A p-value of <0.05 was considered statistically significant.

Table 1
Distribution of Kellgren and Lawrence (KL) grade of the lateral compartment preoperatively according to an increase or decrease in the congruence index (CI) following medial UKA. No significant differences were observed in the distribution of the KL grade of the two groups ($p = 0.85$, Pearson product moment correlation test).

		N (%)
Decrease group	KL I	15 (48%)
N = 31	KL II	16 (52%)
Increase group	KL I	65 (45%)
N = 143	KL II	78 (55%)

Table 2
JSW (±standard deviation) in millimeters preoperative, postoperative and in the control group.

		JSW lateral compartment (mm)	
	Inner	Middle	Outer
Preoperative	5.5 (±2.1)	6.4 (±1.7)	6.8 (±1.7)
Postoperative	6.9 (±2.1)	6.6 (±1.8)	6.1 (±1.4)
Control	7.6 (±1.6)	6.7 (±1.5)	6.0 (±1.1)

3. Results

In the healthy control group, there were 41 knees (15 females, 26 males) with mean age of 33.7 (standard deviation (SD) ± 3.7) years. The mean CI of the lateral compartment was 0.98 (SD ± 0.01). The study group included 159 patients (74 females, 85 males) with 174 medial UKAs who met the inclusion criteria for final analysis. The mean age at the time of surgery was 65.5 (SD ± 10.1) years. The average preoperative mechanical axis alignment of patients who underwent medial UKA was 7.9° (±3.7°) of varus, which decreased to 2.8° (±2.9°) of varus postoperatively ($p < 0.0001$). Preoperatively, 103 knees had a KL grade I of their lateral compartment and 71 knees a grade II.

The mean preoperative lateral compartment CI was 0.88 (SD ± 0.1), which improved significantly to 0.93 (SD ± 0.03) following implantation of a medial UKA (paired *t*-test, $p < 0.001$) (Figure 3). The postoperative lateral compartment CI difference with the control group remained significant ($p = 0.01$). Group A (knees with increased CI after surgery) included 143 (82%) knees, with mean preoperative and postoperative CI of 0.87(SD ± 0.1) and 0.95 (SD ± 0.05), respectively. Group B (knees with decreased CI after surgery) included 31 (18%) knees, with mean preoperative and postoperative CI of 0.92(SD ± 0.08) and 0.88 (SD ± 0.09), respectively. The mean preoperative CI in group B was significantly higher than mean preoperative CI in group A (paired *t*-test, $p = 0.03$). There was no significant difference regarding age, gender and the preoperative KL grade distribution of the lateral compartment between group A and group B (Table 1).

3.1. Joint space width

Analyzing the inner preoperative JSW, we noted that it was significantly narrower in comparison with the control group (paired *t*-test, $p < 0.001$) (Table 2 & Figure 4). Following medial UKA, the inner JSW significantly increased (paired *t*-test, $p < 0.001$). Postoperatively no significant differences were noted in the inner JSW, comparing it to the control group (paired *t*-test, $p = 0.11$). The middle JSW of the lateral compartment did not change significantly following medial UKA implantation. No significant differences were noted in the middle JSW, when comparing the preoperative width with the control (paired *t*-test, $p = 0.46$), the change following UKA implantation (paired *t*-test, $p = 0.16$) and the postoperative width with the control (paired *t*-test, $p = 0.85$). The outer JSW of the lateral compartment differed significantly preoperatively in comparison to the control group (paired *t*-test, $p < 0.001$). We observed that the pre-existing outer JSW became significantly narrower following medial UKA implantation (paired *t*-test, $p = 0.03$), and did not show significant differences postoperatively compared to the control group (paired *t*-test, $p = 0.76$).

No correlation was found between CI alterations, JSW ($r = 0.12$), alignment ($r = -0.07$) and the preoperative KL grade of the lateral compartment ($r = 0.20$). The ICC between the two observers was 0.94 for the CI and 0.99 (95% confidence interval 0.89 to 0.99) for the JSW, showing an excellent inter-observer reliability of both methods.

4. Discussion

The primary surgical options available for the treatment of isolated, medial compartment osteoarthritis of the knee are high tibial osteotomy (HTO), UKA and TKA [24]. Recent improvements in UKA implant designs and surgical techniques have led to higher functional scores [1,25,26], improved range of motion [26], lower complications rate [27,28] and a faster return to sports and work [29] following UKA when compared to TKA. Concerns remain, however, regarding progression of OA in the lateral compartment after medial UKA and the time until revision surgery is needed [2]. This study is the first to demonstrate a significant improvement in the congruity of the lateral compartment of the knee following implantation of a medial UKA. Although the postoperative lateral compartment CI difference with the control group remained significant ($p = 0.01$), the CI in the lateral compartment improved significantly (paired *t*-test, $p < 0.001$) from 0.88 (SD ± 0.1) preoperatively to 0.93 (SD ± 0.03) following medial UKA implantation. Furthermore our data suggests that medial UKA implantation also restores JSW of the lateral compartment, since the existing significant JSW differences preoperatively with the control group, were absent postoperatively. Therefore, we can conclude that medial UKA is not only a resurfacing procedure that affects the medial compartment of the knee, as it also affects the biomechanics of lateral compartment of the knee, and may improve the congruence and restores JSW of the lateral compartment. Potentially, this could prevent or delay the progression of degeneration of the lateral compartment following medial UKA, which is a well-known factor of medial UKA failure.

However, this study also demonstrated that in 18% of the medial UKAs, there was a decrease in the lateral compartment CI. It was observed mainly in knees with a relatively high preoperative CI. This suggests that we should have tight intra-operative control for alignment and tibiofemoral subluxation in order to minimize the risk for lateral compartment CI alterations following medial UKA and be aware of this possible complication, especially in patients with high preoperative CI.

There are a few limitations to our study. First, the study was a retrospective radiographic review and did not evaluate clinical outcomes. Second, the study was a single surgeon case series with extensive experience in performing UKAs using a robotic-assisted surgical technique, and thus these results may not be reproducible at other centers. The majority of UKAs are performed with conventional instrumentation, and use of a robotic-assisted surgical technique may limit the generalizability of our results. A third limitation is that our measurements were performed using AP, standing, tunnel view radiographs, so our congruence evaluation was based on the 2D coronal plane measurements only.

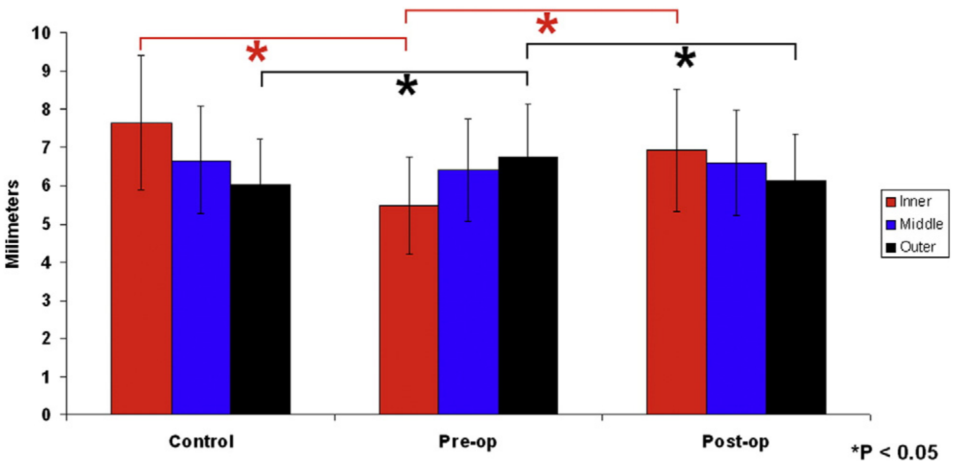

Figure 4. JSW of the lateral compartment preoperatively, postoperatively and in the control group. No significant postoperative differences were noted of the lateral compartment following medial UKA implantation in comparison to the control group (error bars presenting the SD).

Congruence changes in the sagittal plane were not taken into account. Fourth, JSW and CI were measured on radiographs that were obtained six weeks following surgery. Therefore long-term conclusions cannot be drawn from these results and need to be investigated in the future. Finally, we are not able to determine the clinical impact of changes in the lateral compartment CI in this study. We present data on the normal lateral compartment CI from control patients and on the CI in a large group of patient with medial compartment OA. We demonstrate that lateral compartment CI improves after medial UKA in most cases. However, we do not know what CI represents a “pathologic” value and when the CI achieves a level of congruence that allows for effective load distribution and compartment preservation.

Despite these limitations, this study remains important as it presents a novel method for measuring joint congruence and it is the first study, which accurately evaluates the indirect alteration of the lateral compartment following medial UKA. Future studies should be focused on the long-term clinical implications following changes in knee compartment congruence and JSW, along with surgical indications and techniques that may improve the congruence of the lateral compartment following a medial UKA. Our findings suggest that in the majority of patients receiving a well-conducted medial UKA, congruence and of the lateral compartment are improved and JSW is restored, therefore potentially delaying the progression of OA of the lateral compartment. Future studies are needed to evaluate the congruence index and JSW alterations over time and their influence on clinical outcomes scores and implant survivorship results.

References

[1] Zuiderbaan HA, van der List JP, Khamaisy S, Nawabi DH, Thein R, Ishmael C, et al. Unicompartmental knee arthroplasty versus total knee arthroplasty: which type of artificial joint do patients forget? Knee Surg Sports Traumatol Arthrosc 2015.

[2] Pandit H, Hamilton TW, Jenkins C, Mellon SJ, Dodd CA, Murray DW. The clinical outcome of minimally invasive phase 3 Oxford unicompartmental knee arthroplasty: a 15-year follow-up of 1000 UKAs. Bone Joint J 2015;97-B:1493–500.

[3] Heyse TJ, Khefacha A, Peersman G, Cartier P. Survivorship of UKA in the middle-aged. Knee 2012;19:585–91.

[4] Newman J, Pydisetty RV, Ackroyd C. Unicompartmental or total knee replacement: the 15-year results of a prospective randomised controlled trial. J Bone Joint Surg Br Vol 2009;91:52–7.

[5] van der List JP, McDonald LS, AD Pearle. Systematic review of medial versus lateral survivorship in unicompartmental knee arthroplasty. Knee 2015.

[6] Hunter DJ, Sharma L, Skaife T. Alignment and osteoarthritis of the knee. J Bone Joint Surg Am 2009;91(Suppl. 1):85–9.

[7] Khamaisy S, Zuiderbaan HA, Thein R, BP Gladnick, AD Pearle. Coronal tibiofemoral subluxation in knee osteoarthritis. Skeletal Radiol 2015.

[8] Nam D, Khamaisy S, Gladnick BP, Paul S, Pearle AD. Is tibiofemoral subluxation correctable in unicompartmental knee arthroplasty? J Arthroplasty 2013.

[9] Roemhildt ML, Beynnon BD, Gauthier AE, Gardner-Morse M, Ertem F, Badger GJ. Chronic in vivo load alteration induces degenerative changes in the rat tibiofemoral joint. Osteoarthritis and cartilage/OCARS, 21. Osteoarthritis Research Society; 2013. p. 346–57.

[10] Hurwitz DE, Ryals AR, Block JA, Sharma L, Schnitzer TJ, Andriacchi TP. Knee pain and joint loading in subjects with osteoarthritis of the knee. J Orthop Res 2000;18:572–9.

[11] Tanamas S, Hanna FS, Cicuttini FM, Wluka AE, Berry P, Urquhart DM. Does knee malalignment increase the risk of development and progression of knee osteoarthritis? A systematic review. Arthritis Rheum 2009;61:459–67.

[12] Pelletier JP, Raynauld JP, Berthiaume MJ, Abram F, Choquette D, Haraoui B, et al. Risk factors associated with the loss of cartilage volume on weight-bearing areas in knee osteoarthritis patients assessed by quantitative magnetic resonance imaging: a longitudinal study. Arthritis Res Ther 2007;9:R74.

[13] Hunter DJ, Zhang YQ, Tu X, Lavalley M, Niu JB, Amin S, et al. Change in joint space width: hyaline articular cartilage loss or alteration in meniscus? Arthritis Rheum 2006;54:2488–95.

[14] Zuiderbaan HA, Khamaisy S, Thein R, Nawabi DH, Pearle AD. Congruence and joint space width alterations of the medial compartment following lateral unicompartmental knee arthroplasty. Bone Joint J 2015;97-B:50–5.

[15] Weidow J, Pak J, Karrholm J. Different patterns of cartilage wear in medial and lateral gonarthrosis. Acta Orthop Scand 2002;73:326–9.

[16] Hudek R, Schmutz S, Regenfelder F, Fuchs B, Koch PP. Novel measurement technique of the tibial slope on conventional MRI. Clin Orthop Relat Res 2009;467:2066–72.

[17] Tokuhara Y, Kadoya Y, Nakagawa S, Kobayashi A, Takaoka K. The flexion gap in normal knees. An MRI study. J Bone Joint Surg Br Vol 2004;86:1133–6.

[18] Pearle AD, O'Loughlin PF, Kendoff DO. Robot-assisted unicompartmental knee arthroplasty. J Arthroplasty 2010;25:230–7.

[19] Roche M, O'Loughlin PF, Kendoff D, Musahl V, Pearle AD. Robotic arm-assisted unicompartmental knee arthroplasty: preoperative planning and surgical technique. Am J Orthop (Belle Mead NJ) 2009;38:5–10.

[20] Hernigou P, Deschamps G. Alignment influences wear in the knee after medial unicompartmental arthroplasty. Clin Orthop Relat Res 2004;161-5.

[21] Khamaisy S, Zuiderbaan HA, Thein R, Nawabi DH, Joskowicz L, Pearle AD. Coronal tibiofemoral subluxation: a new measurement method. Knee 2014;21:1069–71.

[22] Buckland-Wright JC, Macfarlane DG, Lynch JA, Jasani MK, Bradshaw CR. Joint space width measures cartilage thickness in osteoarthritis of the knee: high resolution plain film and double contrast macroradiographic investigation. Ann Rheum Dis 1995;54:263–8.

[23] Munro BH. Statistical methods for health care research. Philadelphia: Lippincott; 1997.

[24] Mont MA, Stuchin SA, Paley D, Sharkey PF, Parvisi J, Tria Jr AJ, et al. Different surgical options for monocompartmental osteoarthritis of the knee: high tibial osteotomy versus unicompartmental knee arthroplasty versus total knee arthroplasty: indications, techniques, results, and controversies. Instr Course Lect 2004;53:265–83.

[25] Lyons MC, MacDonald SJ, Somerville LE, Naudie DD, McCalden RW. Unicompartmental versus total knee arthroplasty database analysis: is there a winner? Clin Orthop Relat Res 2012;470:84–90.

[26] Dalury DF, Fisher DA, Adams MJ, Gonzales RA. Unicompartmental knee arthroplasty compares favorably to total knee arthroplasty in the same patient. Orthopedics 2009;32.

[27] Griffin T, Rowden N, Morgan D, Atkinson R, Woodruff P, Maddern G. Unicompartmental knee arthroplasty for the treatment of unicompartmental osteoarthritis: a systematic study. ANZ J Surg 2007;77:214–21.

[28] Brown NM, Sheth NP, Davis K, Berend ME, Lombardi AV, Berend KR, et al. Total knee arthroplasty has higher postoperative morbidity than unicompartmental knee arthroplasty: a multicenter analysis. J Arthroplasty 2012;27:86–90.

[29] Walton NP, Jahromi I, Lewis PL, Dobson PJ, Angel KR, Campbell DG. Patient-perceived outcomes and return to sport and work: TKA versus mini-incision unicompartmental knee arthroplasty. J Knee Surg 2006;19:112–6.