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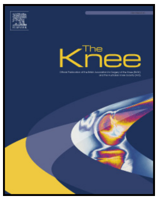

Influence of tibial component rotation on short-term clinical outcomes in Oxford mobile-bearing unicompartmental knee arthroplasty

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ABSTRACT

Background: Malposition of tibial components is an important factor for complications in unicompartmental knee arthroplasty (UKA), but the direct relationship between clinical outcomes and position of tibial component remains unknown. We aimed to investigate whether tibial component rotation in the axial plane could affect clinical outcomes after UKA.

Methods: A total of 50 patients with anteromedial osteoarthritis of the knee underwent Oxford mobile-bearing UKA in this study. Patient-derived clinical scores using the Oxford Knee Score (OKS) and the functional activities of Knee Society Score (KSSF) were assessed preoperatively, and then after one year and two years following surgery. Postoperative tibial component rotation angles using two reference lines in the axial plane were assessed using three-dimensional computed tomography two weeks postoperatively. External rotation of the tibial component relative to each reference line was considered a positive value. We analysed the sequential change of the OKS and KSSF using repeated measures analysis of variance ($P < 0.05$). The effects of tibial component rotation on the OKS and KSSF were analysed using linear regression analysis.

Results: OKS and KSSF showed significant recovery between the preoperative and one-year postoperative period. Rotation angles of tibial components had significant negative correlations with the recovery of the OKS in the two years following UKA.

Conclusions: Tibial component rotation played an important role in improving clinical outcomes during the two years following Oxford mobile-bearing UKA. A trend towards poor outcome was observed when the tibial component was placed at a higher angle of external rotation.
Level of evidence: III.

1. Introduction

Oxford mobile-bearing unicompartmental knee arthroplasty (UKA) provides significant benefit to patients with anteromedial osteoarthritis (OA) [1], with good long-term results. The morbidity and mortality rates after UKA are low, and recovery is quick. Recent studies have shown that good clinical outcomes can be achieved with the Oxford mobile-bearing UKA in patients with medial compartment disease [2–7].

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In contrast to total knee arthroplasty (TKA), tibial component rotation in UKA has wide deviation. The tibial component tends to rotate externally due to a lack of a distinct landmark for tibial component rotation in the small operating field [8–10]. Therefore, we made a tibial vertical cut with the blade directed at the anterior superior iliac spine (ASIS), outside of the operating field, according to the Oxford partial knee surgical technique. Tsukamoto et al. [11] recommended a new anteroposterior (AP) rotational reference line of the tibia connecting the medial intercondylar tubercle and medial border of the patellar tendon at the articular surface level. This has been proved to be useful for the angles relative to the surgical epicondylar axis (SEA) and Akagi's line [12]. Although the ideal tibial component rotation in UKA is well debated, the direct relationship between postoperative tibial component rotation and clinical outcomes is not clearly described.

Rotational mismatch between femoral and tibial components is a crucial risk factor that may contribute to unsuccessful TKA, resulting in pain, stiffness, polyethylene wear and patellofemoral dysfunction [13–17]. It is mainly caused by rotational malposition of the tibial component [18]. Whether mismatch occurs even in the case of UKA as it does in TKA is unknown. In this study, we aimed to investigate whether tibial component rotation in the axial plane could influence tibiofemoral rotational mismatch and postoperative clinical outcomes after Oxford UKA.

2. Material and methods

The study protocol was approved by the Ethics Committee of our hospital. Patients provided informed consent for inclusion in this study. Inclusion criteria were substantial pain and loss of function due to anteromedial OA of the knee [1]. All patients had primary OA of the medial compartment with full-thickness lateral compartment articular cartilage and an intact anterior cruciate ligament (ACL). In addition to the knee condition, patients whose outcome scores could be measured in the outpatient clinic two years after surgery were included in the study. Exclusion criteria were knees with fixed flexion of more than 15°, active knee joint infection and bilateral UKA. Between 2012 and 2015, 50 knees that met the inclusion criteria and underwent primary medial Oxford UKA (Zimmer Biomet, Warsaw, IN) were enrolled. The patient population comprised 33 women and 17 men (age 72.9 ± 6.7 years old, body mass index 25.9 ± 3.7 kg/m^2). Among these patients, the average preoperative coronal plane alignment on standard weight-bearing AP radiographs was 6.7 ± 5.1° in varus. All surgeries were performed by the same surgeon – the senior author (T.H.) – or surgeons instructed directly by him.

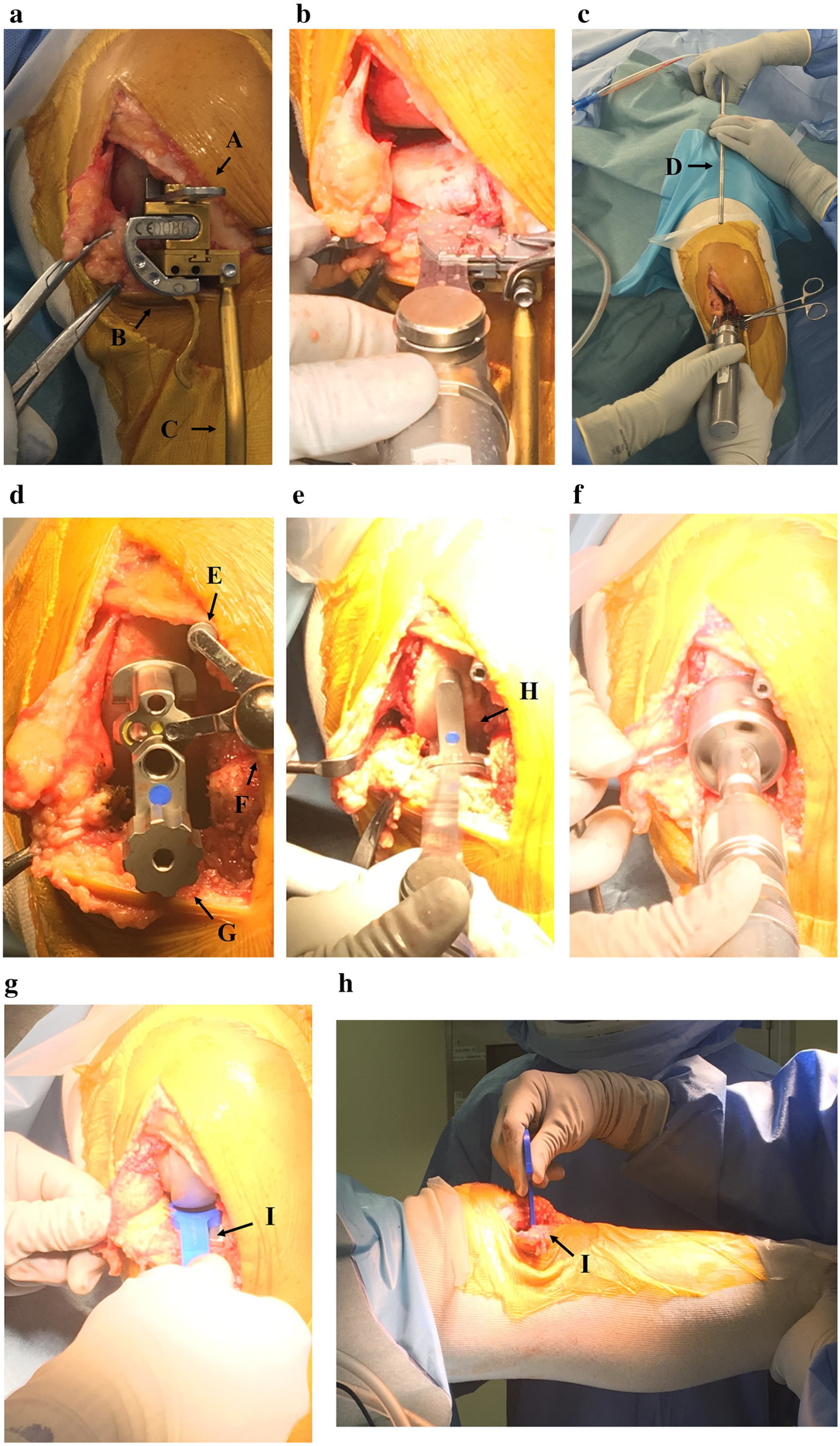
2.1. Operative procedures

All surgeries were performed according to Oxford partial knee surgical technique using an inflatable thigh tourniquet, and the draped leg was placed in a thigh support with the hip flexed to approximately 30°. We used a minimally invasive approach, and the skin was incised from the medial margin of the patella to a point three centimeter distal to the joint line. The incision was deepened through the joint capsule. At its upper end, the capsular incision was extended proximally one centimeter into the vastus medialis. After removal of osteophytes, the tibia was cut using the same method. First, a horizontal cut was made with reference to the posterior condyle of the femur using a femoral sizing spoon and a G-clamp and tibial saw guide, which had seven degrees of built-in posterior slope set parallel to the long axis of the tibia in the coronal and sagittal planes (Figure 1(a), (b)). We then made a vertical cut at the medial edge of the ACL insertion on the tibia with the blade directed at the ASIS in knee flexion, while touching ASIS and showing direction with the alignment rod by assistant (Figure 1(c)). Before the femoral saw cut, a drill hole was made with the femoral drill guide linked to the intramedullary rod (Figure 1(d)). Next, we inserted the posterior resection guide into the drilled holes and cut the posterior femoral condyle (Figure 1(e)). After first milling the condyle using 0-spigot (Figure 1(f)), we performed a gap-balancing technique using the feeler gauge to make the extension gap equal to the flexion gap (Figure 1(g), (h)). Subsequently, we performed final milling of the condyle using optimal spigot.

2.2. Image technique

We performed computed tomography (CT) scans using a 64-row multislice CT system. Patients were in a supine position on the CT table. Scans of 1.25-mm slices were performed from the hip joint to the ankle joint with the patient in a knee-extended position with the patella facing upward. The obtained image datasets were imported into the three-dimensional software (Aquarius Net; Tera Recon, San Mateo, CA). The operating window of the software comprises three multiplanar reformation viewers in the frontal, sagittal and axial planes. In each of the three operating windows, the reconstructed image may be simultaneously rotated, cut and measured as the operator desires. All radiographic assessments were performed by the same two people who operated the software to measure angles and lengths on a virtual cut surface of the proximal tibia.

Figure 1. (a) The femoral sizing spoon (A) was inserted under the posterior condyle of the femur. The tibial saw guide (C) had seven degrees of built-in posterior slope set parallel to the long axis of the tibia in the coronal and sagittal planes. The femoral sizing spoon and the tibial saw guide were connected using a G-clamp (B). Once the G-clamp was locked holding the femoral sizing spoon and tibial saw guide in place, the guide was pinned. (a) The tibial horizontal cut was made after removal of the G-clamp and femoral sizing spoon. (b) The direction of the tibial vertical cut was indicated using an alignment rod (D) by an assistant. (c) The intramedullary link (F) was inserted into the intramedullary rod (E) and into the femoral drill guide (G). (d) Femoral saw cut was made using posterior resection guide (H). (e) Milling of the femoral condyle. (f) Gap balancing technique at extension using the feeler gauge (I). (g) Gap balancing technique at flexion using the feeler gauge (I).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2.3. Assessment of change in tibiofemoral rotational mismatch during UKA

We defined the knee rotation angle (KRA) according to the method reported by Watanabe et al. [18]. SEA was identified as the line that connected the lateral epicondylar prominence and the lowest point of the medial sulcus of the medial epicondyle [19]. The line through the midpoint and perpendicular to the SEA was defined as the femoral AP axis. The AP axis described by Akagi et al. was selected as the tibial AP axis [12]. Knee rotation mismatch was defined as the angle between the femoral AP axis and the tibial AP axis, projected onto the femoral transverse plane (Figure 2). Negative values were used to indicate internal rotation of the tibia relative to the femur, with positive values as external rotation.

2.4. Postoperative assessment of tibial component rotation

The axial alignment of the tibial component was assessed by drawing a line tangential to the lateral wall of the tibial component. Rotation of the tibial component was measured using two reference lines: Akagi's line (angle α) and a line perpendicular to SEA (angle β). External rotation of the tibial component relative to each reference line was considered a positive value (Figure 3 (a), (b)).

2.5. Oxford Knee Score

Oxford Knee Score (OKS) was used as a measure of outcomes. OKS is a patient-based questionnaire that allows the patient to report levels of both functional activity and symptoms. It has previously been validated for use in patients suffering from degenerative arthrosis of the knee [20]. We evaluated patient-reported measurements using a translated, validated Japanese version of OKS (0–48 points) preoperatively, and then after one year and two years following UKA [21].

2.6. Knee Society Score

The 2011 Knee Society Knee Scoring System (KSS) was developed as a new patient-derived outcome measure to better characterise satisfaction, expectations and physical activities after TKA [22]. We evaluated functional activities (0–100 points) of KSS (KSSF) preoperatively, and then after one year and two years following UKA.

2.7. Statistical analysis

All radiographical measurements were performed by an orthopaedic surgeon and were repeated at two-month intervals. To evaluate intraobserver and interobserver reproducibility, measurements were performed twice by one surgeon and once by another examiner on 10 knees randomly selected from the study group. The intraclass correlation coefficients between the two measurements made by the same observer were 0.88, 0.86, 0.94 and 0.88 for measurements of pre- and postoperative KRA,

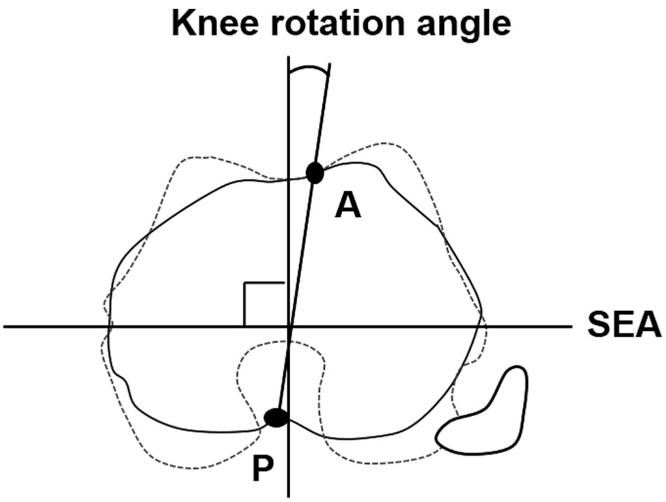

Figure 2. The angle between the tibial anteroposterior axis and perpendicular to the femoral surgical epicondylar axis (SEA) was defined as the knee rotation angle in the femoral transverse plane. A, medial border of the patellar tendon attachment at the tibial tuberosity; P, middle of the tibial attachment of the posterior cruciate ligament.
(This figure was modified from previous reported figure by Watanabe et al. [18])

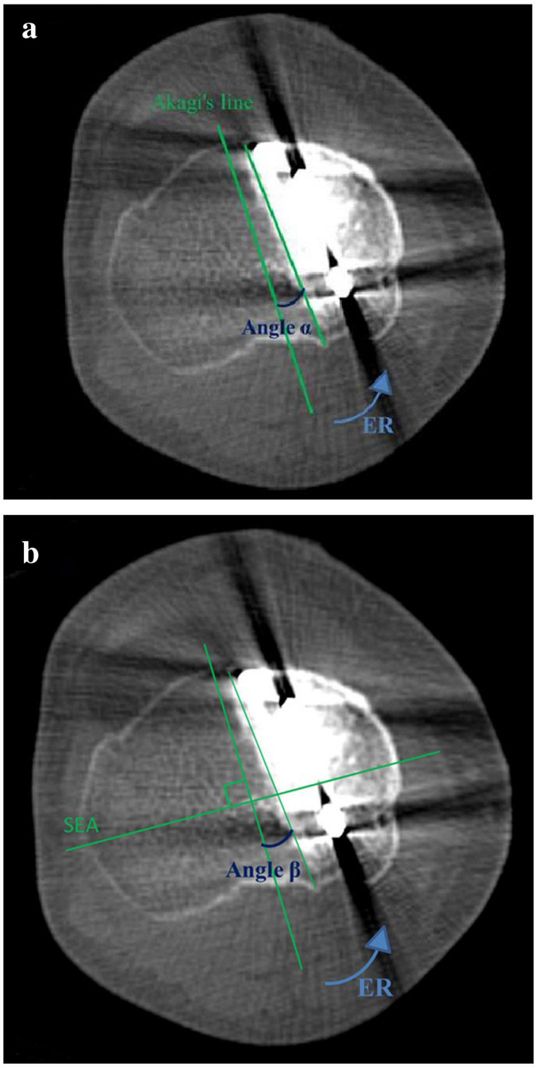

Figure 3. Angle α, tibial component rotation relative to Akagi's line; angle β, tibial component rotation relative to line perpendicular to surgical epicondylar axis (SEA). External rotation (ER) of the tibial component relative to each reference line was considered positive.

and angle α and angle β, respectively. The interclass correlation coefficient was calculated from the mean of two measurements made by different investigators. The coefficients of the angle were 0.91, 0.90, 0.84 and 0.86, respectively.

All values are presented as mean ± standard deviation (SD). Results were analysed using StatView 5.0 (Abacus Concepts Inc., CA, USA). The difference between pre- and postoperative KRA was analysed using paired *t*-test ($P < 0.05$). Sequential change in clinical scores (OKS, KSSF) was then analysed with repeated measures analysis of variance ($P < 0.05$). Finally, we performed linear regression analysis to assess correlation between tibial component position (angle α, angle β) and KRA and clinical scores (OKS, KSSF).

Statistical power analysis was performed before the study, which was expected to require a power of 0.8 based on a pre-specified significance level of $\alpha < 0.05$ and assuming a medium effect size (effect size $f^2 = 0.15$) using G power 3 [23]. The estimated sample size was 43 patients. $P < 0.05$ was considered statistically significant.

3. Results

3.1. Pre- and postoperative KRA

The mean KRA pre-UKA was −0.9 ± 3.4° (range, −8.8 to 7.5), and after UKA KRA was decreased ($P < 0.05$), with a mean of −2.6 ± 3.3° (range, −7.8 to 3.0). The change in KRA (postKRA − preKRA) was −1.6 ± 4.4° (range, −11.1 to 7.7).

3.2. Postoperative tibial component rotation

The mean postoperative angle α and angle β were 4.00 ± 4.60° (range, −6.4 to 12.7) and 2.43 ± 4.15° (range, −5.6 to 9.8), respectively.

3.3. OKSs

The average OKSs were 27.0 ± 7.0 points (range, 13–36), 36.7 ± 6.1 points (range, two to 46) and 37.2 ± 7.9 points (range, 22–48) preoperatively and at one year and two years following UKA, respectively. The average recovery point of OKS during the two years following UKA was 10.2 ± 8.0 points (range, −8 to 24). Sequential changes in OKS are shown in Figure 4. The OKS showed significant recovery from preoperative to one year postoperative ($P < 0.05$), but no significant recovery was found after the first postoperative year (Figure 4(a)).

3.4. KSSs

The average KSSFs were 61.1 ± 21.1 points (range, five to 100), 81.1 ± 12.6 points (range, 35–100) and 80.4 ± 15.3 points (range, 35–100) preoperatively and at one year and two years following UKA, respectively. The average recovery point of KSSF during the two years following UKA was 19.2 ± 21.2 points (range, −25 to 85). Sequential changes in KSSF are shown in Figure 4. The KSSF showed significant recovery from preoperative to one year postoperative ($P < 0.05$), but no significant recovery was found after the first postoperative year (Figure 4(b)).

3.5. Correlation between tibial component rotation and change in KRA

Angle α showed a negative correlation with change in KRA ($r = -0.65$, $P < 0.05$) (Figure 5(a)), but angle β showed no correlation with change in KRA.

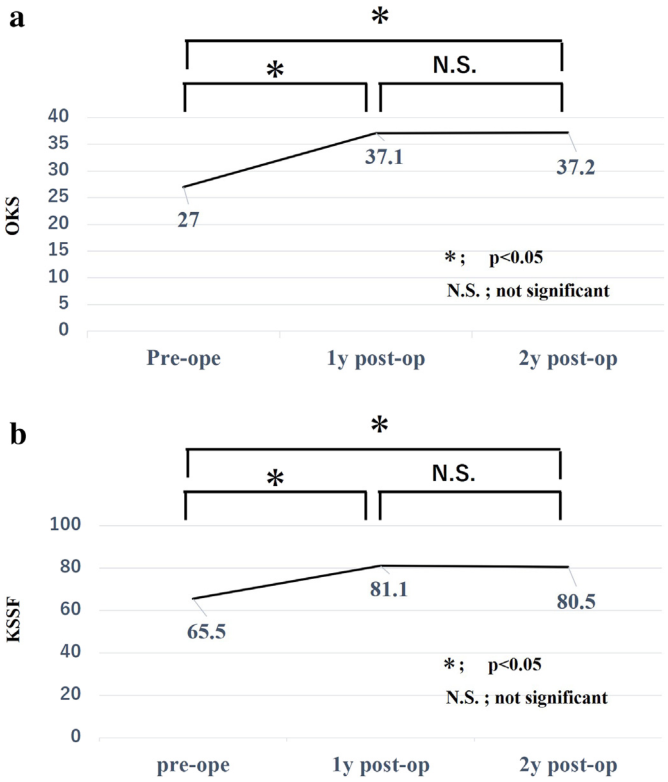

Figure 4. (a) The sequential change of Oxford Knee Score from preoperative to two years postoperatively. (b) The sequential change of functional categories of Knee Society Score from preoperative to two years postoperatively.

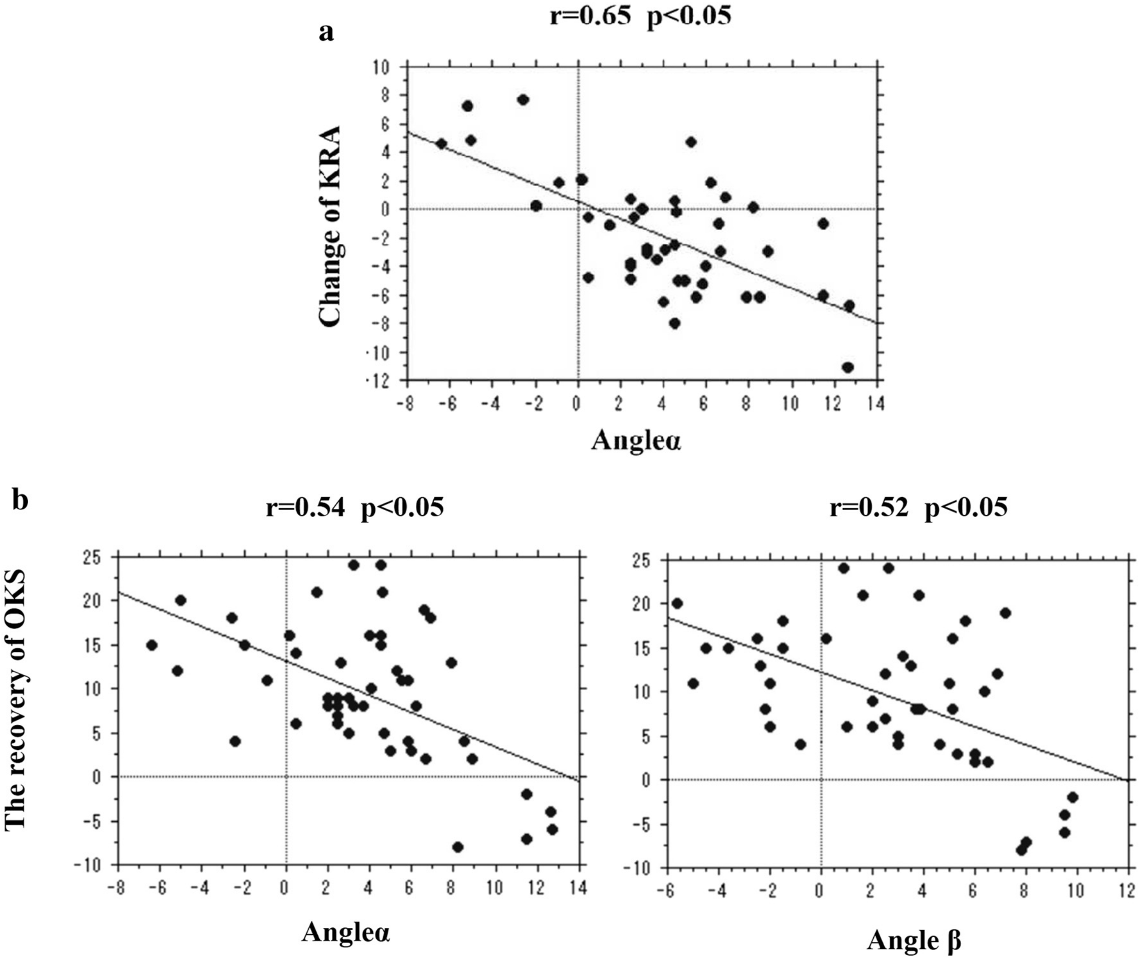

Figure 5. (a) Correlation between the rotation angle of tibia components (angle α) and the change of knee rotation angle. (b) Correlation between rotation angles of tibial component (angle α, angle β) and the recovery of Oxford Knee Score during the two years following surgery.

3.6. Correlation between tibial component rotation and outcome scores (OKS, KSSF)

Correlation coefficients of tibial component rotation and change in KRA with the outcome scores (OKS, KSSF) are shown in Table 1. Both angle α and angle β showed a negative correlation with two-year postoperative OKS ($r = -0.54$, $P < 0.05$) ($r = -0.49$, $P < 0.05$) and KSSF ($r = -0.52$, $P < 0.05$) ($r = -0.34$, $P < 0.05$), respectively, but showed no correlation with preoperative OKS and KSSF. In addition, we found a negative correlation between both angles and recovery of OKS ($r = -0.55$, $P < 0.05$) ($r = -0.52$, $P < 0.05$) (Figure 5(b)). We also found weak correlation between both angles and the recovery of KSSF ($r = -0.27$, $P = 0.09$) ($r = -0.30$, $P = 0.08$), which did not reach a significant level.

4. Discussion

Patient-reported clinical outcomes assessed using OKS and KSS after Oxford mobile-bearing UKA were affected by tibial component rotation in anteromedial OA knees. This finding implies that an optimally implanted tibial component is extremely

Table 1
Correlation coefficient between tibial component rotation and outcome measures.

	OKS preoperative	OKS 2 years postoperative	Recovery of OKS	KSSF preoperative	KSSF 2 years postoperative	Recovery of KSSF
Angle α	0.02	−0.54*	−0.55*	−0.17	−0.52*	−0.27
Angle β	−0.04	−0.49*	−0.52*	0.08	−0.34*	−0.30

Angle α, the rotation angle of the tibial component with reference to Akagi's line; angle β, the rotation angle of tibial component with reference to surgical epicondylar axis. KSSF, functional categories of Knee Society Score; OKS, Oxford Knee Score.

* Correlations are statistically significant ($P < 0.05$).

important for favourable postoperative clinical outcomes after UKA. To the best of our knowledge, this study is the first to describe the effects of tibial component rotation on patient-reported outcomes after Oxford UKA.

Several authors reported that the rotation of tibial component is external, 6.5 ± 5.1° [8] and 11.1° (between −1 and 32) [9]. Therefore, tibial component rotation has wide variation and tends to be externally rotated. In this study, the mean rotation of tibia components was 4.0°, slightly lower than those of previous reports [8, 9]. However, wide variation was observed in the present study when tibial sagittal cut was made directed at ASIS as Lee et al. previously pointed out. The wide variation in tibial component rotation was considered to be due to the direction of tibial sagittal cut line constrained by the lateral wall of the medial condyle, which also has a wide variation in positional relation to ASIS. Kawahara et al. [24] reported the usefulness of the medial wall of the intercondylar notch as tibial rotational reference. They demonstrated that the medial wall of the intercondylar notch was within 5° internal or external rotation relative to the Akagi's line in 73.3% of knees (33/45) using MRI at knee flexion. However, the subjects of their study were normal healthy knees. In OA knees that require surgeries, degeneration and osteophytes of the intercondylar wall may change the positional relationship of these landmarks and reduce the accuracy. Therefore, we should investigate the relationships of these anatomical landmarks in OA knees at both knee extension and flexion in the near future.

It is still unclear why tibial vertical cut tends to be externally rotated. Akagi's line is widely used as a rotational reference of the tibia. Originally, Akagi's line was obtained reference to line perpendicular to epicondylar axis using CT of the knee extension position [12]. However, tibia internally rotated relative to the femur in the process of tibial cut at knee flexion because of the medial pivot motion of the knee. This may be one of the reasons why the tibial component tends to be externally rotated relative to Akagi's line when we use ASIS or femur as reference of tibial vertical cut. These above-mentioned matters suggest the importance of controlling lower-leg rotation to perform a tibial sagittal cut with appropriate rotation without being influenced by the positional relationship with the femur and/or the need for a device to set the sagittal cut with minimum variability.

With regard to rotational mismatch, change in KRA occurred even in UKA and was negatively correlated with tibia component rotation. This result indicates that the tibia tends to move internally, rotating relative to SEA when the tibial component is placed in a higher external rotation in the axial plane. However, in this study, the change in KRA was 1.6°, which is smaller than that of TKA (7.9°) reported by Watanabe et al. [18]. This small value, unlike in TKA, may be affected by the function of the ACL in addition to the posterior cruciate ligament. Care should be taken not to overvalue the clinical sense of a difference as small as 1.6°, even if a statistical significant *P*-value has been achieved.

We also found that the recovery of OKS was negatively correlated with postoperative rotation angles of tibial components using two reference lines (angle α and angle β). These results suggest that excessive external rotation of tibial components is likely to cause pain and result in poor ability to perform daily living activities after UKA. Excessive external rotation of the tibia component may cause dissociation of the bearing from the lateral wall of tibial component with increased risk of bearing spin-out in extension and bearing hitting in flexion.

Regarding tibial component coverage, several authors reported that under- or overhang of tibial component led to poorer clinical outcome. Underhang of the tibial cut surface may result in edge loading on the tibial polyethylene and insufficient bone support of the tibial component on the cut surface [25]. By contrast, medial overhang of the tibial component of 3 mm or more can significantly worsen the OKS and pain score [26]. A cadaveric study showed that a medial overhang of more than two millimeters increases the load to the medial collateral ligament, which is a possible cause of pain [27]. Malrotation of tibia components may affect coverage of the cut surface. Kawahara et al. [24] reported the good coverage of the tibial cut plane for commercially available UKA tibial components when tibial vertical cut was performed with reference to the medial wall of the intercondylar notch. However, the effect of rotational error on tibial component coverage has not been reported and should be investigated in the near future. If this hypothesis is proved, it is also consistent with the results of this study that tibial component rotation affected the clinical outcome.

This study has several limitations. First, the follow-up terms were short. Since one of the concerns in UKA is the tibial component wear or subsidence, rotational angle could be an important variable in this regard. Therefore, long-term study would be needed to verify long-term survival. Second, Oxford UKA includes a mobile meniscal bearing. In contrast to fixed-bearing UKA, in addition to rotation of the tibial component, the effect of bearing location distance should also be evaluated. Third, the study population was limited to Japanese patients undergoing UKA. The shape of the tibia might be different in other populations, and further studies of different and larger populations are necessary. Fourth, there was bias due to different surgeons. However, all surgeries were performed under the same senior surgeon or under instruction by him to minimise this bias. Finally, the relationship between tibial component rotation and coverage was not elucidated.

5. Conclusions

Change in knee rotational mismatch was observed in UKA, which was a lower angle compared to TKA and was affected by tibial component rotation. Tibial component rotation plays an important role in improving clinical outcomes in the two years following Oxford mobile-bearing UKA installation. A trend towards poor outcomes was observed when the tibial component was placed at a higher angle of external rotation.

Conflicts of interest

The authors declare that they have no conflicts of interest. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

[1] White SH, Ludkowski PF, Goodfellow JW. Anteromedial osteoarthritis of the knee. J Bone Joint Surg Br 1991;73:582–6.
[2] Price AJ, Webb J, Topf H, Dodd CA, Goodfellow JW, Murray DW, et al. Rapid recovery after oxford unicompartmental arthroplasty through a short incision. J Arthroplasty 2001;16:970–6.
[3] Pandit H, Jenkins C, Gill HS, Barker K, Dodd CA, Murray DW. Minimally invasive Oxford phase 3 unicompartmental knee replacement: results of 1000 cases. J Bone Joint Surg Br 2011;93:198–204.
[4] Murray DW, Goodfellow JW, O'Connor JJ. The Oxford medial unicompartmental arthroplasty: a ten-year survival study. J Bone Joint Surg Br 1998;80:983–9.
[5] Svard UC, Price AJ. Oxford medial unicompartmental knee arthroplasty. A survival analysis of an independent series. J Bone Joint Surg Br 2001;83:191–4.
[6] Robertsson O, Knutson K, Lewold S, Lidgren L. The routine of surgical management reduces failure after unicompartmental knee arthroplasty. J Bone Joint Surg Br 2001;83:45–9.
[7] Emerson Jr RH, Hansborough T, Reitman RD, Rosenfeldt W, Higgins LL. Comparison of a mobile with a fixed-bearing unicompartmental knee implant. Clin Orthop Relat Res 2002:62–70.
[8] Servien E, Fary C, Lustig S, Demey G, Saffarini M, Chomel S, et al. Tibial component rotation assessment using CT scan in medial and lateral unicompartmental knee arthroplasty. Orthop Traumatol Surg Res 2011;97:272–5.
[9] Iriberri I, Aragon JF. Alignment of the tibial component of the unicompartmental knee arthroplasty, assessed in the axial view by CT scan: does it influence the outcome? Knee 2014;21:1269–74.
[10] Lee SY, Chay S, Lim HC, Bae JH. Tibial component rotation during the unicompartmental knee arthroplasty: is the anterior superior iliac spine an appropriate landmark? Knee Surg Sports Traumatol Arthrosc 2017;25:3723–32.
[11] Tsukamoto I, Akagi M, Mori S, Inoue S, Asada S, Matsumura F. Anteroposterior rotational references of the tibia for medial unicompartmental knee arthroplasty in Japanese patients. J Arthroplasty 2017;32:3169–75.
[12] Akagi M, Oh M, Nonaka T, Tsujimoto H, Asano T, Hamanishi C. An anteroposterior axis of the tibia for total knee arthroplasty. Clin Orthop Relat Res 2004:213–9.
[13] Eckhoff DG, Metzger RG, Vandewalle MV. Malrotation associated with implant alignment technique in total knee arthroplasty. Clin Orthop Relat Res 1995:28–31.
[14] Berger RA, Crossett LS, Jacobs JJ, Rubash HE. Malrotation causing patellofemoral complications after total knee arthroplasty. Clin Orthop Relat Res 1998:144–53.
[15] Incavo SJ, Wild JJ, Coughlin KM, Beynnon BD. Early revision for component malrotation in total knee arthroplasty. Clin Orthop Relat Res 2007;458:131–6.
[16] Barrack RL, Schrader T, Bertot AJ, Wolfe MW, Myers L. Component rotation and anterior knee pain after total knee arthroplasty. Clin Orthop Relat Res 2001:46–55.
[17] Wasielewski RC, Galante JO, Leighty RM, Natarajan RN, Rosenberg AG. Wear patterns on retrieved polyethylene tibial inserts and their relationship to technical considerations during total knee arthroplasty. Clin Orthop Relat Res 1994:31–43.
[18] Watanabe S, Sato T, Omori G, Koga Y, Endo N. Change in tibiofemoral rotational alignment during total knee arthroplasty. J Orthop Sci 2014;19:571–8.
[19] Berger RA, Rubash HE, Seel MJ, Thompson WH, Crossett LS. Determining the rotational alignment of the femoral component in total knee arthroplasty using the epicondylar axis. Clin Orthop Relat Res 1993:40–7.
[20] Dawson J, Fitzpatrick R, Murray D, Carr A. Questionnaire on the perceptions of patients about total knee replacement. J Bone Joint Surg Br 1998;80:63–9.
[21] Takeuchi R, Sawaguchi T, Nakamura N, Ishikawa H, Saito T, Goldhahn S. Cross-cultural adaptation and validation of the Oxford 12-item knee score in Japanese. Arch Orthop Trauma Surg 2011;131:247–54.
[22] Scuderi GR, Bourne RB, Noble PC, Benjamin JB, Lonner JH, Scott WN. The new Knee Society Knee Scoring System. Clin Orthop Relat Res 2012;470:3–19.
[23] Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. Behav Res Methods 2009;41:1149–60.
[24] Kawahara S, Matsuda S, Okazaki K, Tashiro Y, Iwamoto Y. Is the medial wall of the intercondylar notch useful for tibial rotational reference in unicompartmental knee arthroplasty? Clin Orthop Relat Res 2012;470:1177–84.
[25] Lee YS, Yun JY, Lee BK. Tibial component coverage based on bone mineral density of the cut tibial surface during unicompartmental knee arthroplasty: clinical relevance of the prevention of tibial component subsidence. Arch Orthop Trauma Surg 2014;134:85–9.
[26] Chau R, Gulati A, Pandit H, Beard DJ, Price AJ, Dodd CA, et al. Tibial component overhang following unicompartmental knee replacement — does it matter? Knee 2009;16:310–3.
[27] Gudena R, Pilambaraei MA, Werle J, Shrive NG, Frank CB. A safe overhang limit for unicompartmental knee arthroplasties based on medial collateral ligament strains: an in vitro study. J Arthroplasty 2013;28:227–33.