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Correction of coronal alignment correlates with reconstruction of joint height in unicompartmental knee arthroplasty

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Objectives

Because there have been no standard methods to determine pre-operatively the thickness of resection of the proximal tibia in unicompartmental knee arthroplasty (UKA), information about the relationship between the change of limb alignment and the joint line elevation would be useful for pre-operative planning. The purpose of this study was to clarify the correlation between the change of limb alignment and the change of joint line height at the medial compartment after UKA.

Methods

A consecutive series of 42 medial UKAs was reviewed retrospectively. These patients were assessed radiographically both pre- and post-operatively with standing anteroposterior radiographs. The thickness of bone resection at the proximal tibia and the distal femur was measured radiographically. The relationship between the change of femorotibial angle (δFTA) and the change of joint line height, was analysed.

Results

The mean pre- and post-operative FTA was 180.5° (172.2° to 184.8°) and 175.0° (168.5° to 178.9°), respectively. The mean δFTA was 5.5° (2.3° to 10.1°). The joint line elevation of the tibia (JLET) was 4.4 mm (2.1 to 7.8). The δFTA was correlated with the JLET (correlation coefficient 0.494, p = 0.0009).

Conclusions

This study indicated that there is a significant correlation between the change of limb alignment and joint line elevation. This observation suggests that it is possible to know the requirement of elevation of the joint line to obtain the desired correction of limb alignment, and to predict the requirement of bone resection of the proximal tibia pre-operatively.

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Article focus

- As there have been no standard methods to determine the thickness of resection for the proximal tibia pre-operatively, these are determined with intra-operative findings, which primarily depend on the surgeon's experiences
- The purpose of this study was to clarify the correlation between the change of limb alignment and the change of joint line height at the medial proximal tibia and distal femur
- The hypothesis was that the change of limb alignment correlated with the change of joint line height

Key messages

- There was a significant correlation between the correction of FTA (δFTA) and the joint line elevation of the tibia (JLET)
- This observation can make it possible to know the requirement of elevation of joint line to obtain their desired correction of limb alignment and to predict the requirement of bone resection at proximal tibia pre-operatively

Strengths and limitations

- Strength - With this study's results, the surgeon can pre-operatively know the requirement of the elevation of the joint

line in order to obtain the desired correction of limb alignment
- Limitation - the amount of the ligamentous balance was not quantified

Introduction

Unicompartmental knee arthroplasty (UKA) is an effective surgical procedure for relieving pain and restoring function in patients with localised osteoarthritis (OA) of the knee.[1-4] Accuracy of implant positioning and restoring the proper limb alignment are required for the long-term survival of the implants.[5] A neutral correction or slight undercorrection in the coronal alignment is advocated in the literature.[6] Hernigou et al[7] showed that severe undercorrection of the deformity was a cause of increased polyethylene wear. On the other hand, OA in the contralateral compartment can occur after surgery where there has been overcorrection of the pre-existing varus deformity.[8]

Some studies have reported factors that can affect post-operative limb alignment.[9-11] Kim et al[12] reported that limb alignment was affected by the thickness of the bearing, rather than alignment of the femoral and tibial implants. While the limb alignment is determined by the position of the implant in total knee arthroplasty (TKA), it is corrected by the restoration of the joint line at the affected compartment in UKA.[13,14] The correction of limb alignment is mainly formed by the elevation (restoration) of the joint line at the tibia and femur, especially for medial OA.

The change of the joint line at the tibial side is affected by the difference between the depth of resection at the proximal tibia and the thickness of the bearing insert.[10] Similarly, at the femoral side, the change of the joint line is affected by the depth of resection at the distal femur. If the pre-operative varus deformity is very mild and no correction is required, the proximal tibia and distal femur should be resected for the same thickness of the thinnest component. In contrast, if there is a pre-operative varus deformity due to wear of cartilage and subchondral bone at the medial tibia and femur, the joint line should be restored by elevation of the medial joint line. In this case, the bearing insert should be thicker than the resected bone. As there have been no standard methods to determine the thickness of resection of the proximal tibia pre-operatively, resection thickness is determined intra-operatively based on the surgeon's experience. Information about the relationship between the joint line elevation (JLE) and the change of limb alignment would be useful for pre-operative planning. However, to our knowledge, no studies about the relationship between reconstruction of the joint line and correction of limb alignment have been reported.

The purpose of this study was to clarify the correlation between the change of limb alignment and the change of joint line height at the medial proximal tibia and distal femur in UKA. The clinical relevance of this study is that based on this information, the surgeon can pre-operatively predict the requirement of bone resection at proximal tibia to obtain their desired correction of limb alignment. In this study, the pre- and post-operative radiographs of 42 patients who underwent UKA for medial compartment were retrospectively reviewed, and the changes of medial joint line and the femorotibial angle (FTA) were measured. The hypothesis was that the change of limb alignment would correlate with the change of joint line height.

Materials and Methods

A consecutive series of 42 medial UKAs between December 2008 and June 2013 at our institution were reviewed retrospectively. There were nine males and 33 females with a mean age of 71.7 years (59 to 86). The inclusion criteria included patients with OA or osteonecrosis at the medial compartment of the knee, age > 60 years, no flexion contracture more than 15° or no limitation of flexion < 100°, and no dysfunction of cruciate ligaments and collateral ligaments. Furthermore, a long-leg anteroposterior (AP) radiograph was taken while a 15 kg valgus stress was being applied to the knee. If the mechanical axis of the leg was passed at the point from medial 40% to 60% of the knee joint surface on the valgus stress long-leg radiograph, the case was included.[15] Exclusion criteria were inflammatory joint diseases or severe osteoporosis, previous high tibial osteotomy and septic lesion, severe obesity > 35 of body mass index, and severe bone defect > 10 mm. There was no case of arthroplasty for lateral compartment OA. This study protocol was reviewed and approved by the institutional review board at our university. All patients had given their informed consent in advance, from which their radiographs would be used for retrospective studies without their specific permission.

Surgical procedures. All procedures were undertaken using minimally invasive techniques with a quadriceps-sparing approach without reversing or subluxation of the patella. At first, the proximal tibia was prepared using an extramedullary system. The resection angle was adjusted to be perpendicular to the mechanical axis of the tibia in the coronal plane and to be parallel to the posterior slope of the original medial tibial plateau in the sagittal plane. The rotational alignment of the tibia was adjusted to be parallel to the medial wall of the intercondylar notch in 90° of flexion.[16] The depth of resection for the proximal tibia was determined according to an intra-operative joint laxity test in order that a 9 mm extension gap would be obtained after the resection of the proximal tibia. After the resection of the proximal tibia, the cutting alignment and the gaps in both of extension and flexion were assessed. If either gap was < 9 mm, an additional 1 mm to 2 mm cut or adjustment of the posterior slope was performed.

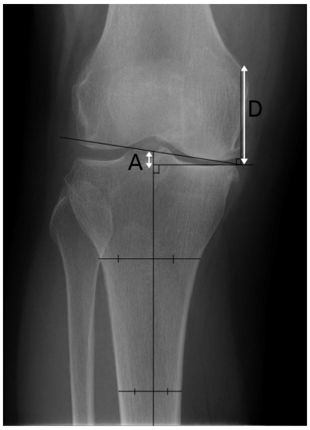

Fig. 1a

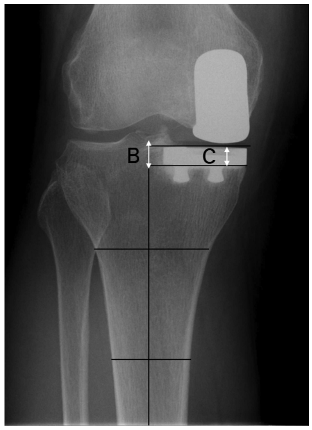

Fig. 1b

Pre-operative anteroposterior radiographs showing a) the distance between the adductor tubercle as the distal point on the medial condylar slope of the femur and the joint line (line D) and b) the depth of resection was defined as differences between distance A and distance B. Line C was the thickness of the tibial insert used to correct magnification.

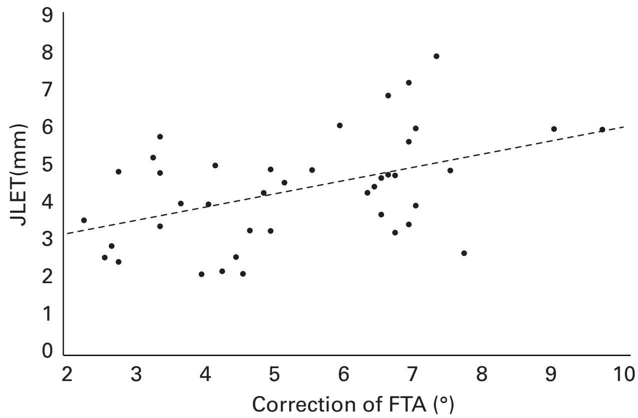

Fig. 2

Graph showing the correlation between joint line elevation of the tibia (JLET) and the correction of the femorotibial angle (δFTA). The slope was 0.4, and the intercept was 2.4. JLET was calculated using the following equation: JLE = 0.4 δFTA + 2.4.

Ligamentous releases were limited to the deep layer of the medial collateral ligament on the tibial side. After the resection of the proximal tibia, a spacer block with optimal thickness to obtain a neutral limb alignment was inserted to fill the extension gap, and the distal femur was resected in parallel to the tibial cut surface in order to accommodate the thickness of the femoral implant. Similarly, the posterior femur was also resected in parallel to the tibial cut surface in flexion to accommodate the thickness of the implant. With trial components in place, the movement and laxity of the knee were tested. The thickness of the polyethylene insert was chosen to leave a 2 mm laxity between the components in both extension and flexion. All implants used were the Zimmer Unicompartmental (Zimmer Inc., Warsaw, Indiana), which were metal-backed cemented tibial components. Following surgery, patients began routine physiotherapy with weight bearing as tolerated.

Radiographic evaluation. The patients were assessed radiographically both pre- and post-operatively with standing AP radiographs. The radiographs were taken on the tangential direction to the tibial baseplate or medial joint surface of the proximal tibia. The FTA was measured and the correction of FTA (the difference between the pre- and post-operative radiograph; δFTA) was calculated for each subject. Next, the depth of resection at the proximal tibia was measured using the following method (Fig. 1): both the anatomical axis of the tibia and a line perpendicular to the anatomical axis from the lowest point of the joint line (termed 'line A') were drawn. The distance from the tip of anatomical axis to the intersection between the anatomical axis and line A was measured on the pre-operative AP film ('distance A'). Similarly, both the anatomical axis and a line perpendicular to the anatomical axis from the centre of the bottom line of the tibial baseplate ('line B') were drawn. The distance from the most proximal point of anatomical axis to the intersection between the anatomical axis and line B was measured on the post-operative AP film (termed 'distance B'). The difference between distance A and distance B was defined as the depth of resection of the proximal tibia. Finally, a line parallel to the tibial base plate passing through the lower point of femoral implant ('line C') was drawn. The distance from line C to a line of the tibial baseplate was measured ('distance C').

The details of the thickness of the tibial insert were obtained from the operative records of each patient. The joint line elevation of the tibia (JLET) was defined as the difference between the depth of resection and the thickness of the tibial insert. At the femoral side, the change of the joint height of the femur was measured based on a method previously described.[17] The perpendicular distance between the adductor tubercle as the distal point on the medial condylar slope of the femur and the joint line was measured ('distance D'). The joint line down the femur (JLDF) was defined as the difference between pre- and post-operative distance D.

The magnification of each radiograph was calculated using the thickness of the tibial insert measured in the post-operative film, and the thickness obtained from the operative records. The JLET and JLDF were adjusted by the amount of image magnification.

Statistical analysis. The correlation between δFTA and the JLET was assessed using a simple linear regression model. JMP software version 9.0.2 (SAS, Cray, North Carolina) was used to analyse the data with the level of significance set at $p < 0.05$. A power analysis was performed on correlations ($r = 0.5$, significant level = 0.05, and power = 0.80) to indicate whether sample sizes of 28.2 on correlations could address the questions. The

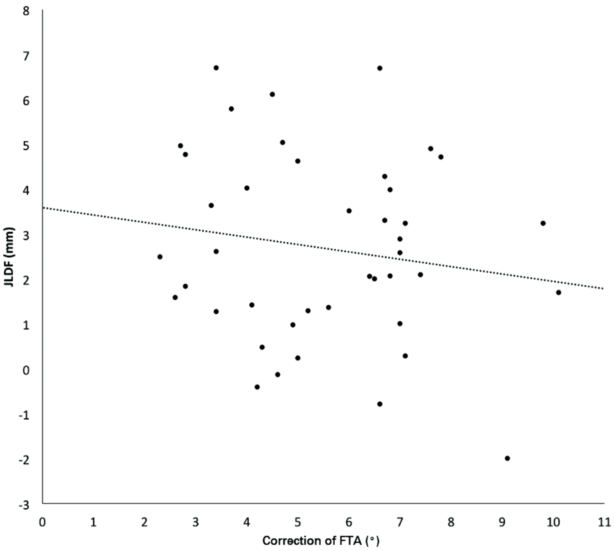

Fig. 3

Graph showing the correlation between the joint line down the femur (JLDF) and the correction of the femorotibial angle (δFTA). There was no correlation.

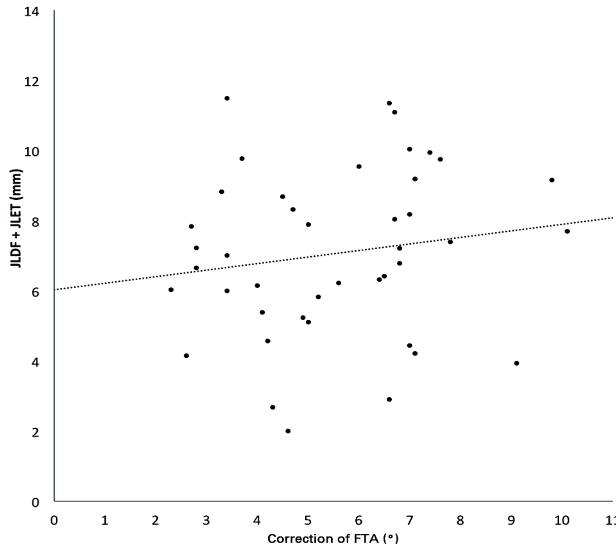

Fig. 4

Graph showing the correlation between the mean change of the joint space (defined as joint line elevation of the tibia (JLET) + joint line down the femur (JLDF)) and the correction of the femorotibial angle (δFTA). There was no correlation.

δFTA and JLET were conducted by one observer (UK) and were repeated in a blinded manner during the course of two sessions. Intraobserver reliabilities, evaluated with the use of the intraclass correlation coefficient, were 0.821 and 0.881 for δFTA and JLET, respectively. Two observers (UK and KM) independently measured 20 randomly selected radiographs. The mean δFTA measured (by UK) was 5.5 (standard deviation (SD) 2.3) and that of KM was 5.5 (SD 2.0). Similarly, the mean JLET measured by UK was 4.2 (SD 1.3) and that of KM was 4.2 (SD 1.2). Inter-observer reliabilities, evaluated with the use of the interclass correlation coefficient, were 0.912 and 0.806 for δFTA and JLET, respectively.

Results

The mean pre- and post-operative FTA were 180.5° (SD 2.4, 172.2° to 184.8°) and 175.0° (SD 2.0, 168.5° to 178.9°), respectively. The mean δFTA was 5.5 (SD 2.0, 2.3° to 10.1°).

The bearing sizes used in this study were 8 mm to 12 mm (mean bearing thickness 9.1 mm). The mean depth of resection at the proximal tibia was 4.7 mm (SD 1.5, 2.0 to 9.3). The mean JLET was 4.4 mm (SD 1.4, 2.1 to 7.8). There was a significant correlation between δFTA and the JLET (correlation coefficient 0.494; $p = 0.0009$). JLET was calculated using the following equation: JLET = 0.4 δFTA + 2.4 (Fig. 2).

The mean JLDF was 2.7 mm (SD 2.1, -2.0 to 6.7). There was no correlation between δFTA and the JLDF (correlation coefficient -0.158, $p > 0.05$; Fig. 3).

The mean change of joint space (defined as JLET + JLDF) was 7.1 mm (SD 2.4, 2.0 to 11.5). There was no correlation with the δFTA (correlation coefficient 0.156, $p > 0.05$; Fig. 4).

Discussion

The most important finding of this study was that the change of limb alignment demonstrated a correlation with the JLET following medial UKA. With this result in mind, the surgeon can pre-operatively calculate the required joint line elevation in order to obtain their desired correction of limb alignment.

The desired correction angle in the coronal alignment can be estimated from δFTA, which is calculated by subtracting the FTA on a pre-operative valgus stress radiograph from that on a standing AP radiograph.[15,18] Tashiro et al[19] suggested that the mean post-operative limb alignment demonstrated a significantly strong correlation with the values on the pre-operative valgus stress radiographs, while the correlation between both the pre- and the post-operative standing alignment, was moderate. A neutral, or slight under correction is recommended as an ideal post-operative coronal alignment.[6]

The surgeon can predict the requirement of bone resection at the proximal tibia from the desired correction angle in order to obtain the ideal post-operative alignment. This information is useful when undertaking pre-operative planning of medial UKA. The equation of the regression line was as follows: JLET = 0.4 δFTA + 2.4 (Fig. 2). The reason for the equation intercept may be the pre-operative thickness of cartilage. With this equation, it is suggested that, for example, it is necessary to elevate the joint line 4.4 mm from the bony surface of the tibia if the surgeon plans to correct the FTA by 5° valgus. In this case, the surgeon should resect 4 mm from the proximal tibia to use an 8 mm bearing insert. However, the condition of the remaining cartilage varies among the cases, and this may have caused the variations of the results of this study. Therefore, the surgeon should determine the amount of resection of the proximal tibia in consideration of the thickness of the remaining cartilage.

According to a report from the Australian Orthopaedic Association National Joint Replacement Registry,[20] the cumulative percentage revision of UKA at eight years was 13.2% compared with 5.0% for TKA. Another registry reported that the primary reasons for revision arthroplasty were progression of OA in other compartments (48%).[21] Furthermore, a study presented lateral OA as the main reason for UKA revision.[22] Squire et al[23] reported that 62 of 136 knees showed progression of OA in the contralateral compartment and seven knees underwent revision for this reason. The risk factors for UKA revision were younger patient age, increased patient weight, use of a thinner tibial component, increased tibial component posterior slope, and lesser or over correction of pre-operative varus limb alignment.[24]

Post-operative alignment is important in order to prevent the progression of degenerative arthritis and implant-related complications. Several studies have reported the effect of post-operative alignment of the knee on the long-term outcome of UKA.[6,7,25,26] For UKA, neutral correction or slight under correction has been recommended as over correction may increase the risk of degeneration in the opposite compartment. Significant under correction, on the other hand, may accelerate polyethylene wear and recurrence of deformity.[7,27]

In contrast to the TKA, the alignment correction of the leg in UKA depends not on the alignment of the component itself, but on the elevation (restoration) of the joint line on the affected side. In this study, there was a significant correlation between δFTA and the JLET, while the change of the joint line of the femur had no significant correlation with δFTA. Because the distal femur is usually resected by the same thickness of the femoral implant, the change of the joint line of the femur was relatively small in our case series. At the tibial side, the elevation of the joint line is determined by the thickness of the implant relative to the bone resection. If the bone resection was 2 mm with the use of 8 mm thickness of the implant, the joint lift length would be 6 mm. If the amount of resection was too short to obtain the optimal joint lift with use of the thinnest component, there would be a risk of over correction of the limb alignment, or the tibia would need to be re-cut. If the amount of resection was too large, there would be a risk of fracture of the tibia or subsidence of the implant.[28-31] Therefore, determining the thickness of bone resection at the proximal tibia is one of the critical points in the operative procedure of UKA. There has not been a standard method to determine or predict the optimal thickness of bone resection pre-operatively, and thus, it primarily depends on the surgeon's experience.

There are some limitations in our study. First, we have not quantified the amount of the ligamentous balance in each case. However, the same surgical criteria for soft-tissue balancing were carried out throughout this studied group. Ligamentous releases were limited to the deep layer of the medial–collateral ligament on the tibial side. In addition, the spacer-guided system is reported to approximate valgus laxity.[32] Furthermore, the purpose of this study was to clarify the relationship between JLE and the change of limb alignment, which is not related to the ligament balance. Second, the depth of tibial resection was evaluated radiographically. The radiograph may cause some variations as a result of technical inconsistencies. However, we chose the radiograph that was taken at a consistent direction and the rate of magnification was adjusted accordingly. Furthermore, radiographic evaluation was performed using standard weight-bearing radiographs. For analysis of the alignment of the lower limb, long-leg standing radiographs are required. However, the purpose of this study was to clarify the relationship between JLE and the change of limb alignment, therefore, the use of a standard weight-bearing radiograph for pre- and post-operative radiographic evaluation was reasonable for the purpose of this study. Also, Skyttä et al[33] reported that the standard AP knee radiograph appeared to be a valid alternative to the hip-to-ankle radiograph for determining the coronal planes of the knee. Finally, we did not assess the clinical outcome with post-operative alignment. However, the assessment of clinical outcome was not the main purpose of this study, and would be a focus of further research.

In conclusion, this study indicates that there is a significant correlation between joint line elevation and the change of limb alignment in UKA. The JLET was calculated using the following equation: JLET = 0.4 δFTA + 2.4. This observation can make it possible to predict the required amount of bone resection of the proximal tibia pre-operatively, in order to achieve JLET, and the desired correction of limb alignment.

References

1. **Berger RA, Meneghini RM, Jacobs JJ, et al.** Results of unicompartmental knee arthroplasty at a minimum of ten years of follow-up. *J Bone Joint Surg [Am]* 2005;87-A:999–1006.
2. **Cartier P, Sanouiller JL, Grelsamer RP.** Unicompartmental knee arthroplasty surgery. 10-year minimum follow-up period. *J Arthroplasty* 1996;11:782–788.
3. **Argenson JN, Blanc G, Aubaniac JM, Parratte S.** Modern unicompartmental knee arthroplasty with cement: a concise follow-up, at a mean of twenty years, of a previous report. *J Bone Joint Surg [Am]* 2013;95-A:905–909.
4. **Valenzuela GA, Jacobson NA, Buzas D, et al.** Unicompartmental knee replacement after high tibial osteotomy: invalidating a contraindication. *Bone Joint J* 2013;95-B:1348–1353.

5. **Whiteside LA.** Making your next unicompartmental knee arthroplasty last: three keys to success. *J Arthroplasty* 2005;20(suppl 2):2–3.

6. **Ridgeway SR, McAuley JP, Ammeen DJ, Engh GA.** The effect of alignment of the knee on the outcome of unicompartmental knee replacement. *J Bone Joint Surg [Br]* 2002;84-B:351–355.

7. **Hernigou P, Deschamps G.** Alignment influences wear in the knee after medial unicompartmental arthroplasty. *Clin Orthop Relat Res* 2004;423:161–165.

8. **Weale AE, Murray DW, Baines J, Newman JH.** Radiological changes five years after unicompartmental knee replacement. *J Bone Joint Surg [Br]* 2000;82-B:996–1000.

9. **Aleto TJ, Berend ME, Ritter MA, Faris PM, Meneghini RM.** Early failure of unicompartmental knee arthroplasty leading to revision. *J Arthroplasty* 2008;23:159–163.

10. **Hopgood P, Martin CP, Rae PJ.** The effect of tibial implant size on post-operative alignment following medial unicompartmental knee replacement. *Knee* 2004;11:385–388.

11. **Iesaka K, Tsumura H, Sonoda H, et al.** The effects of tibial component inclination on bone stress after unicompartmental knee arthroplasty. *J Biomech* 2002;35:969–974.

12. **Kim SJ, Bae JH, Lim HC.** Factors affecting the postoperative limb alignment and clinical outcome after Oxford unicompartmental knee arthroplasty. *J Arthroplasty* 2012;27:1210–1215.

13. **Gulati A, Pandit H, Jenkins C, et al.** The effect of leg alignment on the outcome of unicompartmental knee replacement. *J Bone Joint Surg [Br]* 2009;91-B:469–474.

14. **Shakespeare D, Ledger M, Kinzel V.** Accuracy of implantation of components in the Oxford knee using the minimally invasive approach. *Knee* 2005;12:405–409.

15. **Waldstein W, Bou Monsef J, Buckup J, Boettner F.** The value of valgus stress radiographs in the workup for medial unicompartmental arthritis. *Clin Orthop Relat Res* 2013;471:3998–4003.

16. **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;470:1177–1184.

17. **Iacono F, Raspugli GF, Bruni D, et al.** The adductor tubercle as an important landmark to determine the joint line level in total knee arthroplasty: from radiographs to surgical theatre. *Knee Surg Sports Traumatol Arthrosc* 2014;22:3034–3038.

18. **Keene G, Simpson D, Kalairajah Y.** Limb alignment in computer-assisted minimally-invasive unicompartmental knee replacement. *J Bone Joint Surg [Br]* 2006;88-B:44–48.

19. **Tashiro Y, Matsuda S, Okazaki K, et al.** The coronal alignment after medial unicompartmental knee arthroplasty can be predicted: usefulness of full-length valgus stress radiography for evaluating correctability. *Knee Surg Sports Traumatol Arthrosc* 2014;22:3142–3149.

20. **No authors listed.** Annual report. Hip and knee arthroplasty. Australian Orthopaedic Association National Joint Replacement Registry. https://aoanjrr.dmac.adelaide.edu.au/documents/10180/42728/Annual%20Report%202009?version=1.1&t=1349406243327 (date last accessed 14 July 2015).

21. **Dudley TE, Gioe TJ, Sinner P, Mehle S.** Registry outcomes of unicompartmental knee arthroplasty revisions. *Clin Orthop Relat Res* 2008;466:1666–1670.

22. **Kerens B, Boonen B, Schotanus MG, et al.** Revision from unicompartmental to total knee replacement: the clinical outcome depends on reason for revision. *Bone Joint J* 2013;95-B:1204–1208.

23. **Squire MW, Callaghan JJ, Goetz DD, Sullivan PM, Johnston RC.** Unicompartmental knee replacement. A minimum 15 year followup study. *Clin Orthop Relat Res* 1999;367:61–72.

24. **Collier MB, Eickmann TH, Sukezaki F, McAuley JP, Engh GA.** Patient, implant, and alignment factors associated with revision of medial compartment unicondylar arthroplasty. *J Arthroplasty* 2006;21(suppl 2):108–115.

25. **Kennedy WR, White RP.** Unicompartmental arthroplasty of the knee. Postoperative alignment and its influence on overall results. *Clin Orthop Relat Res* 1987;221:278–285.

26. **Zambianchi F, Digennaro V, Giorgini A, et al.** Surgeon's experience influences UKA survivorship: a comparative study between all-poly and metal back designs. *Knee Surg Sports Traumatol Arthrosc* 2014;23:2074–2080.

27. **Kim KT, Lee S, Kim TW, Lee JS, Boo KH.** The influence of postoperative tibiofemoral alignment on the clinical results of unicompartmental knee arthroplasty. *Knee Surg Relat Res* 2012;24:85–90.

28. **Harada Y, Wevers HW, Cooke TD.** Distribution of bone strength in the proximal tibia. *J Arthroplasty* 1988;3:167–175.

29. **Sneppen O, Christensen P, Larsen H, Vang PS.** Mechanical testing of trabecular bone in knee replacement. *Int Orthop* 1981;5:251–256.

30. **Small SR, Berend ME, Rogge RD, et al.** Tibial loading after UKA: evaluation of tibial slope, resection depth, medial shift and component rotation. *J Arthroplasty* 2013;28 (suppl):179–183.

31. **Weber P, Schröder C, Laubender RP, et al.** Joint line reconstruction in medial unicompartmental knee arthroplasty: development and validation of a measurement method. *Knee Surg Sports Traumatol Arthrosc* 2013;21:2468–2473.

32. **ten Ham AM, Heesterbeek PJ, van der Schaaf DB, Jacobs WC, Wymenga AB.** Flexion and extension laxity after medial, mobile-bearing unicompartmental knee arthroplasty: a comparison between a spacer- and a tension-guided technique. *Knee Surg Sports Traumatol Arthrosc* 2013;21:2447–2452.

33. **Skyttä ET, Lohman M, Tallroth K, Remes V.** Comparison of standard anteroposterior knee and hip-to-ankle radiographs in determining the lower limb and implant alignment after total knee arthroplasty. *Scand J Surg* 2009;98:250–253.

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Author contributions:
- U. Kuwashima: Data collection, Data analysis, Writing the paper
- K. Okazaki: Study design, Data analysis, Performed surgeries, Revising the paper
- Y. Tashiro: Data analysis, Performed surgeries, writing the paper
- H. Mizu-Uchi: Performed surgeries, Revising the paper
- S. Hamai: Performed surgeries, Revising the paper
- S. Okamoto: Data analysis, Revising the paper
- K. Murakami: Data analysis, Revising the paper
- Y. Iwamoto: Study design, Data analysis, Revising the paper

ICMJE Conflict of Interest:
- None declared