Role of alignment in successful clinical outcomes following medial unicompartmental knee arthroplasty: current concepts

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Received 30 September 2019
Revised 5 February 2020
Accepted 3 March 2020

To cite: Petterson, PT, PhD SC, Blood, MD TD, Plancher, MD, MPH KD. *J ISAKOS* Epub ahead of print: [*please include* Day Month Year]. doi:10.1136/jisakos-2019-000401

ABSTRACT

Unicompartmental knee arthroplasty (UKA) has become increasingly more common, indicating the necessity to better understand factors that may impact outcomes and survivorship. Overcorrection or undercorrection of a varus deformity can increase the risk of postoperative complications including contralateral, lateral compartmental osteoarthritis, component loosening, and component wear following medial UKA. There is no general consensus on the amount of alignment correction to optimise outcomes. The purpose of this article is to provide an overview of the current literature related to alignment, intraoperative alignment correction, and the impact on outcomes and survivorship following medial UKA as well as to explore alternative surgical techniques including patient-specific instrumentation and robotic assistance when managing the varus-malaligned knee with medial UKA. Understanding each of these factors and how they interact is vital in providing patients with promising outcomes following UKA. The ideal alignment is unknown; however, the key is to avoid severe undercorrection and overcorrection of varus malalignment for superior outcomes following medial UKA.

Current concepts

- Alignment is a critical part of planning for a unicompartmental knee arthroplasty (UKA).
- Undercorrection of a varus-aligned knee at time of medial UKA may contribute to increased polyethylene wear.
- Residual varus >5–7° is associated with increased risk of revision.
- Overcorrection of varus deformity increases risk of progression of osteoarthritis in the lateral compartment in medial UKA.
- Three-foot standing alignment films are essential for preoperative planning.
- It is unclear if robotics or patient-specific implants will address alignment and lead to improved outcomes.
- Alignment correction of 2–3° optimises outcomes.

Future perspectives

- Long-term studies are needed to investigate the influence of alignment on progression of osteoarthritis in the lateral compartment after medial UKA.
- Cost analyses are needed to determine whether patient-specific instrumentation and robotic-assisted UKA provide a cost–benefit.
- Activity following UKA has been reported at many levels. Studies defining a safe level of sports will help patient selection, especially in active baby-boomers.

INTRODUCTION

Unicompartmental knee arthroplasty (UKA) has evolved to become an alternative to total knee arthroplasty for patients with unicompartmental knee OA. While early results were disappointing,[1] improved implant design, patient selection criteria and surgical technique[2] has led to improved clinical outcomes and survivorship. The rates of UKA have varied widely over the years with 8%–15% of all knee arthroplasties currently being UKA.[3] As the utilisation of UKA continues to increase, it is important to review factors that may be associated with inferior results.

Initial indications described by Kozin and Scott included isolated single-compartment arthritis, osteoarthritis (OA) or osteonecrosis, age greater than 60 years, weight less than 82 kg, an intact anterior cruciate ligament, a varus or valgus angular deformity less than 15° that is passively correctable to neutral, a flexion contracture less than 5°, and knee flexion range of motion greater than 90°.[4] While new studies have supported broader guidelines, new standards have not been defined in all areas.

There is a general belief that alignment plays a role in the outcome and survivorship of UKA; however, optimal alignment has not been well defined. Studies have demonstrated better outcomes with postoperative mechanical axis angles ≤7°. Collier *et al*[5] showed that a postoperative hip–knee angle indicating more varus was one of five factors statistically associated with revision following UKA. Kleeblad *et al*[6] showed that alignment of ≤7° could be achieved in 98% of patients with a large varus deformity (>7°). This study defined optimal alignment of ≤4°. Avoiding undercorrection is necessary to avoid increased wear of the tibial component and recurrence of the deformity as a result of wear.[7] In addition to prosthesis wear, aseptic loosening and progression of OA in the contralateral compartment can result with an undercorrected deformity.

Table 1 Normative mechanical axis and anatomical axis values of the lower limb

Lower limb alignment	Tibiofemoral angle	Description
Mechanical	1.2±2.2° 1±2.8°	The relation between the mechanical axes of the femur and tibia
Anatomical	6.85±1.4°	The relationship between the anatomical axes of the femur and tibia (eg, a line drawn along the length of the intramedullary canal of the femur and tibia, respectively)

In a multicentre study, loosening was the main reason for failure followed by OA progression and wear.[8] Studies have shown that correction of severe deformity can result in good function and quality of life following UKA.[6] The ideal postoperative limb alignment following a medial UKA is not consistent in these studies and remains controversial.[9]

The purpose of this current concept is to review the current literature regarding lower limb deformity and unicompartment knee OA and to discuss the amount of deformity correction necessary for successful outcomes following medial UKA.

ALIGNMENT

Mechanical alignment is the angle of intersection of a line drawn from the centre of the femoral head through the centre of the tibial spines and a line drawn from the centre of the talus through the centre of the tibial spines.[10] Normal, neutral alignment of the knee is considered 1–3° varus[11–13] (table 1). In reviewing the literature, it is critical to determine how malalignment was defined for each study, as different methods of measurement are used.[14 15]

In healthy, normally aligned knees, approximately 70% of the weightbearing forces across the tibiofemoral joint fall in the medial compartment.[16] These forces across the medial compartment increase with increased varus alignment. Therefore, undercorrection of varus alignment in medial UKA can potentially lead to early polyethylene wear and early failure.[17 18] Recently, Danese *et al* showed the volume of compressively overstrained cancellous bone was decreased and anteromedial cortical bone stress was increased with varus malalignment supporting this premise.[19]

INTRAOPERATIVE ALIGNMENT CORRECTION

Malalignment in knee OA corresponds to the combination of constitutional alignment of the lower extremity plus deformation due to the degenerative wear. In patients with constitutional varus, the ideal alignment correction is unknown and correcting to neutral (eg, 1–3° varus) may be undesirable. While the optimal amount of correction is unknown, residual varus of more than 5–7° (eg, undercorrection) has been associated with increased risk of revision.[7]

Deformity due to wear can easily be corrected during UKA, however, the amount of deformation due to wear versus constitutional varus alignment must be determined. The use of navigation systems may assist in differentiating deformation wear and constitutional malalignment.[20] The surgeon must use caution to avoid correcting more than the wear deformation as this could lead to changes in ligament balancing and load distribution. With an overcorrection, the lateral compartment becomes overconstrained, increasing the risk of fast OA development in the contralateral compartment. With an undercorrection, the medial compartment will remain overloaded, which may increase the risk of implant loosening and failure.

Surgical technique to obtain accurate tibiofemoral alignment and restore normal knee kinematics is essential in achieving a favourable outcome. Alignment in medial UKA is determined by the height of the contact point between the medial femoral condyle and the tibial component. It is dependent on the amount of resection of the proximal tibia, ligament stability, preoperative deformity, implant thickness, and surgical technique.[21] Finite-element analyses have demonstrated that 3° of malalignment can lead to a 40% increase in strain at the tibial baseplate bone–cement interface.[22] As UKA is a technically challenging procedure, implant positioning and balance of ligaments is of critical importance. A balanced knee is achieved by proper bone resection and selecting the appropriate polyethylene insert.[23]

Using a musculoskeletal computer simulation, Sekiguchi *et al*[24] reported that tibial component alignment is preferred between neutral and 2° varus in the coronal plane. The authors suggested that varus >4° or valgus alignment and excessive posterior slope can cause excessive medial/lateral translation, which could be related to feelings of instability in patients and cause inferior outcomes.

Determinants of postoperative alignment after UKA have also been investigated. Mullaji *et al*[25] stratified patients by age, body mass index, sex, experience of the surgeon performing the UKA, insert thickness, and preoperative limb alignment. The authors found that preoperative limb alignment was the only significant predictor of postoperative alignment. Thirty-nine percent of knees with excessive preoperative varus (10–15°) had excessive postoperative varus. Zhang *et al*[26] evaluated 122 mobile-bearing medial UKA to determine risk of postoperative valgus malalignment. Regression analysis showed smaller lateral distal femoral angle (LDFA), femerotibial facet angle (FTFA), larger medial proximal tibia angle (MPTA), and less medial tibial cut thickness were associated with postoperative valgus malalignment. In another study, preoperative valgus stress radiography along with the tibia first-cut technique predicted postoperative HKA, which allowed for more accurate correction intraoperatively.[27]

PATIENT-SPECIFIC INSTRUMENTATION

Implant design, especially baseplate and fixation, plays an integral biomechanical role in countering the ill effects of malalignment and diminishes the potential for baseplate loosening.[28] Patient-specific instrumentation (PSI) has been developed with the goal of improving implant positioning and alignment, as well as restoring knee kinematics and function by allowing the surgeon to visualise implant positioning three-dimensionally to determine component alignment before proceeding to the operating room. Using patient-specific cutting blocks designed by preoperative CT scanning, studies have suggested improved accuracy of implant positioning, coronal limb axis, femoral rotation and tibial slope.[29–32] One study found that the change in varus or valgus alignment was on average 0.3°, change in posterior slope was 1.1° and the change in external rotation was 1.5°. Other added benefits of patient-specific instrumentation include shorter surgical time.[33]

While improved implant positioning has been suggested,[30 32] results are not unanimous and the clinical relevance and the cost–benefit ratio are suspect.[34] Van Leeuwen *et al*[35] demonstrated poor agreement between preoperative planning and postoperative alignment in 25 patients with medial UKA using patient-specific positioning guides. Similarly, others have demonstrated no difference in alignment compared with conventional

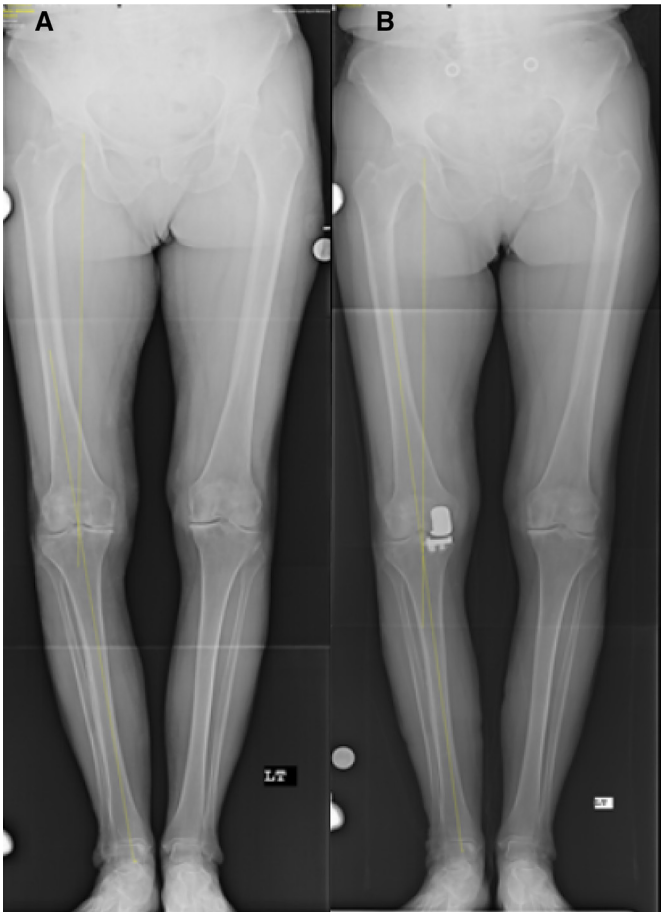

Figure 1 (A) Three-foot standing film demonstrating mechanical alignment (10° varus) of the lower limb in a 75-year-old woman prior to medial unicompartmental knee arthroplasty. (B) Three-foot standing film demonstrating postoperative mechanical alignment (7° varus) in the same patient representing a 3° intraoperative alignment correction.

UKA.[36 37] A randomised clinical trial of 60 patients undergoing either patient-specific versus conventional UKA demonstrated at 1-year follow-up that there was no difference in patient gait spatiotemporal parameters, no difference in limb alignment, or functional outcome.[37] A recent study described midterm outcomes in patients undergoing PSI UKA.[38] The authors concluded that the PSI system was not superior to conventional methods. In a randomised controlled trial, no difference in radiological assessment between PSI and conventional instrumentation was seen; however, the PSI was less accurate with tibial cuts.[38] Further improvement in PSI guides may improve the success of these systems.

ROBOTIC ASSISTANCE

Robotic-assisted devices have also been developed to improve consistency and minimise variability in implant positioning.[39–47] Lonner *et al*[40] compared 31 robot-assisted UKA with 27 conventional UKA and found that the variance of component positioning between cases was 2.6 times greater in the conventional technique, suggesting robotic-assisted surgery results in more consistent implant position. In a randomised controlled trial of 28 knees comparing conventional to robot-assisted medial UKA, robot-assisted surgery accurately positioned the implants to within 2° of the preoperative planned tibiofemoral angle, whereas only 40% of the knees performed with conventional techniques achieved this level of accuracy.[41] In a larger series of 120 knees, the robotic-assisted device was found to be more accurate in achieving femoral component sagittal, axial, and coronal positioning, as well as tibial sagittal and axial positioning compared with conventional methods; however, differences in functional outcomes and failure were not analysed.[42]

In a recent study of robotic-assisted UKA compared with conventional UKA, there was a significantly higher percentage of postoperative limb alignment outliers compared with the control group.[46] In addition, revisions in the control group occurred in association with malposition or limb malalignment, while none of the robotic group occurred due to malposition or limb malalignment.

ALIGNMENT AND OUTCOMES FOLLOWING MEDIAL UKA

A recent biomechanical study suggested that 2° of varus in the coronal plane was preferred for the tibial component.[24] In addition, they stated varus >4° caused increased medial/lateral translation which could affect the outcome.[24] In a multicentre study of 559 medial UKAs in 421 patients, residual varus alignment greater than 5° was associated with mechanical failure compared with patients with less than 5° varus that did not show signs of failure.[48] Hernigou and Deschamps[7] reported increased wear of the polyethylene component and recurrence of varus deformity with undercorrection of the varus deformity intraoperatively. The authors stratified 58 medial UKAs into three groups with 10–20 years of radiographic follow-up: overcorrection to valgus, slight varus and severe undercorrection greater than 10°. Average polyethylene wear rate in the group with undercorrection was greatest at a rate of 0.21 mm/year compared with 0.11 mm/year and 0.14 mm/year in the overcorrected and neutral groups, respectively.

Van der List *et al*[49] assessed the role of alignment in functional outcomes after medial UKA in 143 patients. Intraoperative alignment correction averaged 5°, which shifted limb alignment from a varus aligned knee (average preoperative varus 7.3°) to a neutral alignment (average postoperative limb alignment 2.3°). A more neutral alignment was associated with improved functional outcomes. This has also been demonstrated in several other series.[48 50] However, other studies suggest that optimal outcomes at up to 9-year follow-up can also be achieved with minor residual varus alignment (2–7°).[50]

Overcorrection of a varus deformity, creating a neutral or valgus alignment postoperatively, can also result in the development or progression of OA in the lateral compartment.[40] Overcorrection of varus malalignment shifts the mechanical forces laterally, predisposing the lateral compartment to increased risk for wear and degeneration. Hernigou and Deschamps[7] reported 17% of their medial UKAs were overcorrected with a resultant average valgus deformity of 4°. Sixty percent of the knees that were in valgus postoperatively demonstrated progression of OA in the lateral compartment at an average wear rate of 0.23 mm per year. Similarly, Kim and colleagues[51] demonstrated a strong association between postoperative mechanical axis after medial UKA and long-term failure of the implants. The highest number of failures occurred in patients with 4–6° of valgus postoperatively.

Our consecutive series of 148 knees (average age 65±10 years) with fixed-bearing medial UKA demonstrates the importance of optimal intraoperative limb alignment correction. All patients had a passively correctable varus deformity of less than 18° of varus (average 7° varus alignment) preoperatively. At a minimum of 2-year follow-up, all patients completed clinical

and functional assessments including full radiographic knee series with a 3-foot standing alignment film. Average alignment correction was 2° (less varus compared with preoperative limb alignment) (figure 1). At maximum 13.5-year follow-up, revision rate was 1.4%. Both occurred early in the surgeon's series and were related to technical error. Postoperative alignment did not influence functional outcomes. Patients demonstrated excellent functional outcomes with return to preoperative moderate or vigorous sporting activities with no signs of prosthesis failure or progression of OA in the contralateral compartments.

The decision to proceed with UKA in patients with severe varus deformities should not be taken lightly. In the severely malaligned, varus knee, soft-tissue releases may be needed in addition to medial osteophyte excision in order to restore a more neutral alignment.[52] The surgeon must be cautious to avoid excessive release of the medial collateral ligament to achieve proper ligamentous tensioning. Recently, in a large series of 200 consecutive patients with large preoperative varus deformities (7–18°), UKA was demonstrated to be a successful procedure in this patient setting.[6] Average intraoperative correction was 6° achieving an average postoperative alignment of 4° varus with 98% of patients have a mechanical axis of less than 7° varus. Long-term outcomes are still needed in these patients.

CONCLUSIONS

A uniform consensus on the exact coronal or sagittal alignment needed for optimal results following UKA has not yet been determined. Undercorrection of the varus knee is associated with complications and inferior outcomes following medial UKA. Most research supports a correction of ≤7°, while others suggest more correction is optimal. Several factors can be associated with ideal correction, including surgical technique. Newer surgical techniques, including the use of a robot, may provide greater accuracy in correcting the alignment. The ideal alignment is unknown; however, the key is to avoid severe undercorrection and overcorrection of varus malalignment for superior outcomes following medial UKA.

Contributors KDP made substantial contribution to the design of the work and analysis of the data; and contributed to the drafting of the manuscript and revising it for important intellectual content; and had final approval of the final version; and he agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. SCP contributed to the design of the work and analysis of the data; and contributed to the drafting of the manuscript and revising it for important intellectual content; and had final approval of the final version; and she agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. TDB contributed to the design of the work and analysis of the data; and contributed to the drafting of the manuscript and revising it for important intellectual content; and had final approval of the final version; and he agrees to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article.

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