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

Saker Khamaisy [a], Hendrik A. Zuiderbaan [a,*], Jelle P. van der List [a], Denis Nam [b], Andrew D. Pearle [a]

[a] Sports Medicine and Shoulder Service, Department of Orthopaedic Surgery, Hospital for Special Surgery, Weill Medical College of Cornell University, New York, NY, United States
[b] Adult Reconstruction and Joint Replacement Service, Department of Orthopaedic Surgery, Hospital for Special Surgery, Weill Medical College of Cornell University, New York, NY, United States

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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

* Corresponding author at: Hospital for Special Surgery, 535 E. 70th Street, New York, NY 10021, United States. Tel.: +31 624876539; fax: +31 646 797 8222.
E-mail addresses: saker.khamaisy@gmail.com (S. Khamaisy), hazuiderbaanmd@gmail.com (H.A. Zuiderbaan), vanderlistj@hss.edu (J.P. van der List), namd@wudosis.wustl.edu (D. Nam), pearlea@hss.edu (A.D. Pearle).

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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)

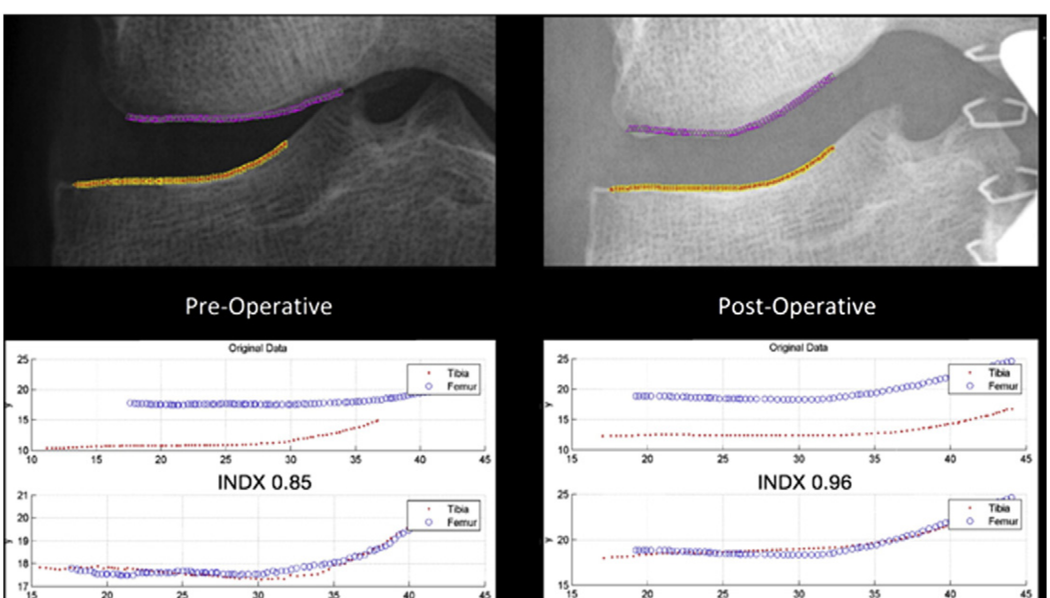

Figure 1. The performed iterative closest point algorithm calculates the congruence index (noted as INDX in the figure) of the lateral compartment pre- and postoperatively following manual digitization of the femoral and tibial surfaces.