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Is Tibiofemoral Subluxation Correctable in Unicompartmental Knee Arthroplasty?

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ABSTRACT

The purposes of this study were to describe a method for measuring tibiofemoral subluxation in UKA, and to report the mean amount of tibiofemoral subluxation seen both preoperatively and postoperatively in a cohort of patients undergoing UKA. Two hundred thirty-five patients who received a medial UKA, and 39 patients who received a lateral UKA, were reviewed. In the medial UKA cohort, the mechanical alignment was corrected from 7.7°±5.9° preoperatively, to 2.9°±2.5° postoperatively, while the tibiofemoral subluxation was corrected from 4.5 mm±3.0 mm preoperatively, to 2.3 mm±2.7 mm postoperatively. In the lateral UKA cohort, the mechanical alignment was corrected from −5.5°±3.8° to −1.6°±3.4°, while the tibiofemoral subluxation was corrected from 4.3 mm±2.7 mm to 2.8 mm±2.5 mm. This study presents a novel method for measurement of tibiofemoral subluxation, the mean amount of tibiofemoral subluxation present preoperatively, and the amount of correction that can be expected during both medial and lateral unicondylar knee arthroplasty.

Unicompartmental knee arthroplasty (UKA) has continued to increase in popularity for the treatment of localized, compartmental osteoarthritis of the knee [1,2]. The number of unicompartmental arthroplasties performed over the last decade has increased by 30%, as patients have demonstrated fewer perioperative complications, along with reduced recovery times versus total knee arthroplasty (TKA) [3,4]. However, there remains debate regarding the appropriate indications and contraindications for UKA. Kozinn and Scott initially suggested that patients weighing more than 82 kg, younger than 60 years of age, "extremely physically active," having chondrocalcinosis on preoperative radiographs or intraoperatively, or with exposed bone in the patellofemoral or contralateral compartments, should not be offered UKA [5]. However, Pandit et al. demonstrated the ten-year survival of patients who received an Oxford UKA, who possessed one of the aforementioned potential contraindications, to be superior to those considered "ideal" candidates (97.0% vs. 93.5%) [6]. Therefore, the relative indications and contraindications for UKA continue to evolve.

One controversial and potential contraindication to UKA, that is less commonly discussed, is the presence of tibiofemoral subluxation in patients with unicompartmental arthritis. Numerous studies note the presence of tibiofemoral subluxation as part of their exclusion criteria for UKA, while others state that if the subluxation is "correctable" on preoperative stress imaging, UKA may still be indicated [7–9]. Berger et al. noted that preoperatively, tibiofemoral subluxation might indicate either instability or contralateral compartment disease, which may be difficult to correct with UKA [8]. However, to our knowledge, the mean amount of tibiofemoral subluxation present in patients undergoing UKA, and its ability to be corrected with UKA, have not yet been determined. In addition, a method of reproducibly measuring tibiofemoral subluxation has not been described in the literature, perhaps contributing to the lack of data to this regard. The purposes of this study were to 1) describe a method for measuring tibiofemoral subluxation in UKA, 2) report the mean amount of tibiofemoral subluxation seen both preoperatively and postoperatively in a cohort of patients undergoing medial and lateral UKA, and 3) to determine potential demographic variables associated with tibiofemoral subluxation.

Materials and Methods

This study is a retrospective review of an institutional review board approved database of a single surgeon. From May 2008 to May 2012, 235 patients underwent a medial UKA for isolated medial compartment osteoarthritis, while from June 2008 to July 2012, 39 patients underwent a lateral UKA for isolated lateral compartment osteoarthritis. Inclusion criteria for this study were patients who received a UKA, and received both preoperative and postoperative standing, anteroposterior (AP) hip-to-ankle radiographs. Indications for performing a UKA were the presence of isolated, medial or lateral compartment osteoarthritis, a flexion contracture of less than 10°, flexion to greater than 90°, and an intact anterior cruciate ligament based on clinical and intraoperative assessments. Exclusion criteria

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were the presence of an inflammatory arthropathy, opposite compartment or patellofemoral compartment degeneration on preoperative radiographs, or suspected pain originating from the patellofemoral compartment on preoperative clinical examination. The severity of the deformity in the coronal plane and the presence of tibiofemoral subluxation were not exclusion criteria for this study. Gender, body mass index (BMI), and age at surgery were recorded for all patients who met our inclusion criteria.

All surgeries were performed by the senior author using a previously described, robotic-arm assisted technique for preparation of both the femoral and tibial surfaces (MAKO Surgical Corp., Ft. Lauderdale, FL) [10,11]. In accordance with the guidelines set forth by Hernigou et al., the goal for both the medial and lateral UKAs was an "undercorrection" of the respective varus and valgus deformities, with avoidance of "overcorrection" and potentially hastened wear in the contralateral compartment [12].

Standing, AP hip-to-ankle radiographs were taken at our institution both preoperatively, and at each patient's first postoperative visit (typically 6 weeks postoperatively), following an established protocol [13]. Care was taken to ensure that each patient stood with their patellae facing forward, to minimize rotational variation among the radiographs. Overall lower extremity mechanical alignment was measured on both preoperative and postoperative films. The method for performing this measurement is demonstrated in Fig. 1. Best-fit circles were placed at the femoral head and at the distal femoral joint line, and a line connecting the centers of these respective circles formed the femoral mechanical axis. Similarly, best-fit circles at both the talar dome, and at the proximal tibial plateau were drawn, and a line connecting the centers of these respective circles formed the tibial mechanical axis. All circles were drawn to fit the most medial and lateral aspects of each anatomic surface. The angle formed between the femoral and tibial mechanical axes was recorded as the overall lower extremity mechanical alignment. For convention, all (+) values corresponded with a varus alignment, and all (−) values corresponded with a valgus alignment.

A method for measuring tibiofemoral subluxation was developed, with the goal of measuring the amount of tibiofemoral subluxation independent of the overall lower extremity angulation (Fig. 2). Standing, AP hip-to-ankle radiographs were again analyzed. Using the prior established tibial mechanical axis, a second line was drawn parallel to the tibial mechanical axis from the apex of the femoral intercondylar notch. A third line was then drawn perpendicular to the two, parallel lines. The distance between the two, parallel lines was then measured and recorded as the tibiofemoral subluxation. For convention, if the line from the apex of the intercondylar notch fell medial to the tibial mechanical axis, the tibiofemoral subluxation was assigned a (+) value (if lateral to the tibial mechanical axis, then a (−) value was assigned). The same method was used for measurement of tibiofemoral subluxation in both the medial and lateral UKA cohorts. Figs. 3 and 4 demonstrate measurement of tibiofemoral subluxation on both preoperative and postoperative radiographs of a patient who received a medial UKA. In addition, measurements of tibiofemoral subluxation were performed for 30 patients without evidence of joint space narrowing or arthritic disease, who possessed standing, AP hip-to-ankle radiographs. These radiographs were performed in patients who presented with knee pain, but subsequently had "normal" radiographs. These measurements were performed to provide a baseline value of tibiofemoral subluxation in patients without osteoarthritis.

All radiographic measurements were independently measured by two observers, and the results were assessed for interobserver reliability.

Statistical Methods

All data was collected and analyzed utilizing Microsoft Excel software (Microsoft Corporation, Redmond, WA). A student's two-tailed t-test was used to compare the preoperative and postoperative values for tibiofemoral subluxation and overall mechanical alignment, with statistical significance set at a *P*-value of <.05.

Interclass correlation coefficients for radiographic measurements were graded using previously described semi-quantitative criteria: excellent for $0.9 \leq r \leq 1.0$, good for $0.7 \leq r \leq 0.89$, fair/moderate for $0.5 \leq r \leq 0.69$, low for $0.25 \leq r \leq 0.49$, and poor for $0.0 \leq r \leq 0.24$ [14]. In addition, correlation coefficients between the values for tibiofemoral subluxation, patient demographics, and mechanical alignment were calculated.

Fig. 1. Radiographs demonstrating measurement of the overall lower extremity mechanical alignment both preoperatively (A), and after placement of a medial UKA (B). In this patient, the preoperative alignment was 11.6°, which was corrected to 6.0° postoperatively.

Results

The medial UKA cohort consisted of 235 patients (120 male, 115 female; 113 right, 112 left), with a mean age of 64.9 ± 10.6 yrs, and a mean body mass index (BMI) of 28.8 ± 6.2 kg/m^2.

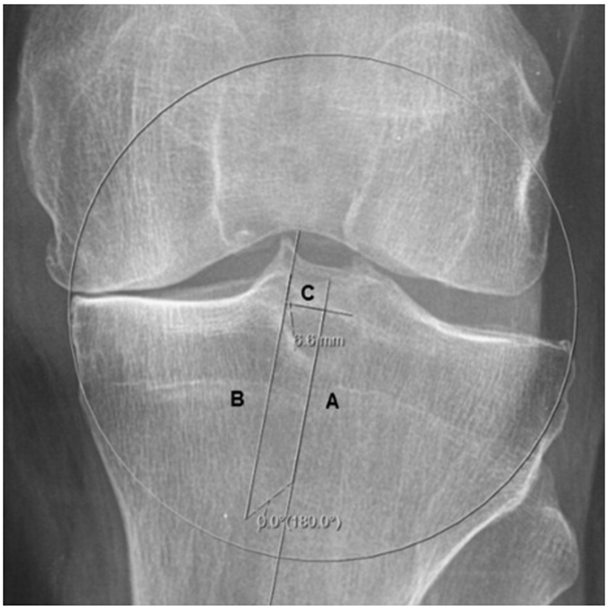

Fig. 2. Radiograph demonstrating measurement of the tibiofemoral subluxation. The tibial mechanical axis is first drawn (A), and a line parallel to the tibial mechanical axis is drawn from the apex of the intercondylar notch (B). The distance between these two, parallel lines (C) was measured, and recorded as the tibiofemoral subluxation (6.6 mm in this example).

The lateral UKA cohort consisted of 39 patients (15 male, 24 female; 22 right, 17 left), with a mean age of 62.7 ± 13.6 yrs, and a mean BMI of 27.9 ± 5.1 kg/m^2.

In the medial UKA cohort, the mean preoperative lower extremity mechanical alignment was 7.7°±5.9°, while the mean postoperative alignment was 2.9°±2.5°, a difference that was statistically significant ($p<0.001$). This corresponded with a mean mechanical alignment correction of 4.8° ± 5.7°. The mean preoperative tibiofemoral subluxation was 4.5 ± 3.0 mm, while the mean postoperative subluxation was 2.3 ± 2.7 mm, a difference that was statistically significant ($p<0.001$). This corresponded with a mean tibiofemoral subluxation correction of 2.2 ± 2.6 mm in the medial UKA cohort (Table 1). No significant correlation was appreciated between the amount of preoperative tibiofemoral subluxation and the preoperative alignment ($r = 0.04$), patient sex ($r = 0.05$), BMI ($r = -0.15$), or age ($r = -0.07$). In addition, the degree of tibiofemoral subluxation correction was found to be independent of the degree of overall mechanical alignment correction ($r = 0.07$).

In the lateral UKA cohort, the mean preoperative lower extremity mechanical alignment was −5.5°±3.8°, while the mean postoperative alignment was −1.6°±3.4°, a difference that was statistically significant ($p<0.001$). This corresponded with a mean mechanical alignment correction of 3.9°±4.1°. The mean preoperative tibiofemoral subluxation was 4.3 ± 2.7 mm, while the mean postoperative subluxation was 2.8 ± 2.5 mm, a difference that was statistically significant ($p<0.001$). This corresponded with a mean tibiofemoral subluxation correction of 1.5 ± 2.0 mm in the lateral UKA cohort. No significant correlation was appreciated between the preoperative tibiofemoral subluxation and the preoperative alignment ($r = 0.16$), patient sex ($r = 0.3$), BMI ($r = 0.01$), or age ($r = -0.16$). In addition, the degree of tibiofemoral subluxation correction was found to be independent of the degree of overall mechanical alignment correction ($r = -0.06$).

Tibiofemoral subluxation and overall mechanical alignment measurements were also performed on 30 patients without radiographic evidence of arthritis or joint space narrowing (mean age 26.8 ± 7.6 yrs). The mean value for tibiofemoral subluxation in this cohort was 2.2 ± 1.0 mm, while the mean lower extremity mechanical alignment was 1.0°±1.9°. The difference between the value for tibiofemoral subluxation in the "normal" patients, and the preoperative values for both the medial and lateral UKA cohorts was statistically significant ($p<0.001$ and $p<0.001$, respectively). However, no significant difference was appreciated between the value for tibiofemoral subluxation in the "normal" patients, and the

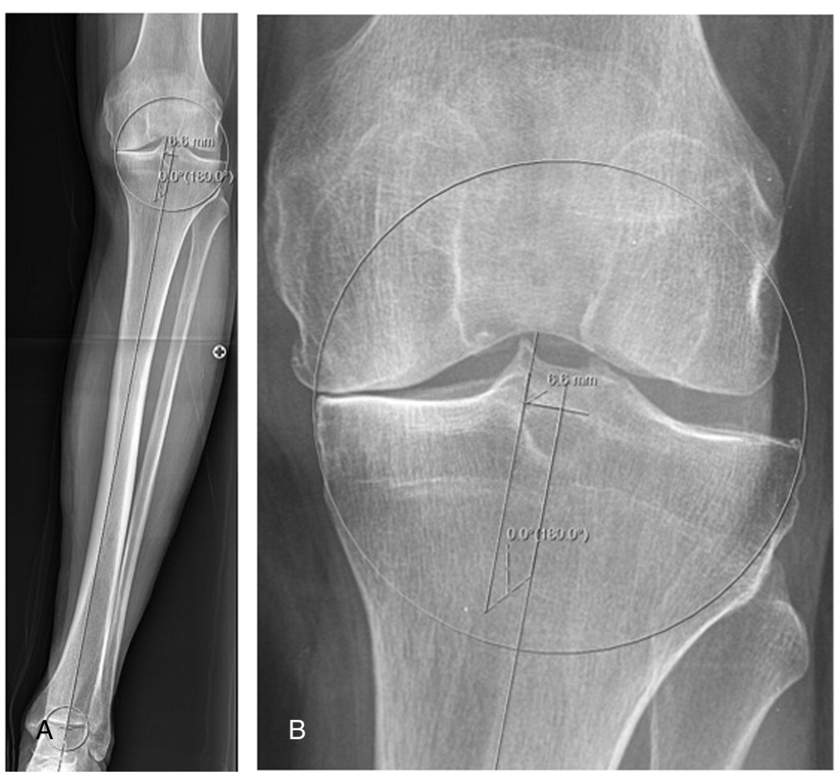

Fig. 3. (A) Radiograph demonstrating measurement of tibiofemoral subluxation on a preoperative radiograph. (B) Magnified view of the same patient centered at the knee joint.

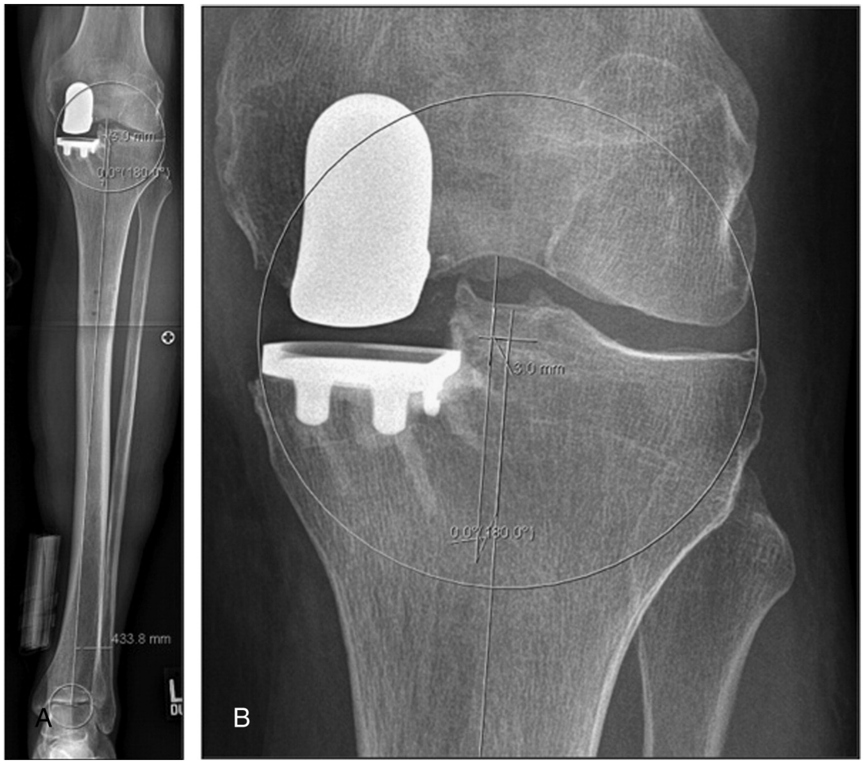

Fig. 4. (A) Radiograph demonstrating measurement of tibiofemoral subluxation after placement of a medial UKA. (B) Magnified view of the same patient centered at the knee joint. In this patient, the tibiofemoral subluxation was 3.0 mm postoperatively.

postoperative values for both the medial and lateral UKA cohorts ($p = 0.75$ and $p = 0.68$, respectively).

Lastly, interobserver correlation coefficients for both overall mechanical alignment and tibiofemoral subluxation were good, with values of 0.78 and 0.86, respectively.

Discussion

Unicondylar knee arthroplasty has continued to increase in popularity, as numerous studies have demonstrated satisfactory implant survivorship, and recent data has demonstrated a decrease in postoperative morbidity and faster recovery when compared to total knee arthroplasties[4,8,15]. However, the indications and contraindications for unicompartmental knee arthroplasty continue to evolve, and concerns remain regarding the increased revision rates seen in registry data when compared to total knee arthroplasties [16]. Baker et al., in an analysis of the National Joint Registry of England and Wales, demonstrated that both the overall revision rate, and the revision rate for "unexplained" pain was higher in the UKA group versus the TKA group. In the UKA cohort, revision for "unexplained pain" comprised 23% of the total revisions, while in the TKA group, revision for "unexplained pain" comprised 9% of the total revisions[16]. Thus, factors that may lead to "unexplained" pain and possibly future revision surgeries must continue to be extrapolated.

Table 1
Table Demonstrating Values for the Overall Mechanical Alignment and Tibiofemoral Subluxation for Both the Medial and Lateral UKA Cohorts. All Values Presented as Mean ± Standard Deviation.

	Medial UKAcohort	Lateral UKACohort
Preoperative mechanical alignment (°)	7.7 ± 5.9	−5.5 ± 3.8
Postoperative mechanical alignment (°)	2.9 ± 2.5	−1.6 ± 3.4
Mean alignment correction (°)	4.8 ± 5.7	3.8 ± 4.1
Preoperative tibiofemoral subluxation (mm)	4.5 ± 3.0	4.3 ± 2.7
Postoperative tibiofemoral subluxation (mm)	2.3 ± 2.7	2.8 ± 2.5
Mean tibiofemoral subluxation correction (mm)	2.2 ± 2.6	1.5 ± 2.0

One radiographic variable that has rarely been studied is the presence of tibiofemoral subluxation on both preoperative and postoperative radiographs in patients undergoing unicompartmental knee arthroplasty. Postoperative tibiofemoral subluxation has been hypothesized to increase the incidences of intercondylar notch impingement, component edge loading, and hasten polyethylene wear [8,17]. Therefore, the purposes of this study were to present a radiographic method of measuring tibiofemoral subluxation in UKA, and to report the mean values for both preoperative and postoperative tibiofemoral subluxation in a large cohort of patients undergoing UKA.

In this study, a method for measuring tibiofemoral subluxation is described, with the goal of measuring the amount of tibiofemoral subluxation independent of the overall lower extremity angulation. This method demonstrated good interobserver reliability, with a correlation coefficient of 0.86. The mean correction of tibiofemoral subluxation in the medial UKA cohort was 2.2 ± 2.6 mm, versus 1.5 ± 2.0 mm in the lateral UKA cohort. Interestingly, in both cohorts, the amount of tibiofemoral subluxation correction did not correlate with the amount of overall, mechanical alignment correction. In addition, the amount of preoperative subluxation demonstrated little to no correlation with the patient's sex, age, BMI, or degree of preoperative deformity. Therefore, this information suggests tibiofemoral subluxation to be a variable that may present to varying degrees independent of the patient's demographic variables, or overall, mechanical alignment. One potential explanation for this finding may be related to the bone quality present in the affected compartment. For example, if a patient with medial compartment osteoarthritis has soft bone in the medial compartment, they may be more prone to have bone deformation with increased varus angulation, rather than tibiofemoral subluxation. In contrast, a patient with hard, sclerotic bone may experience increased tibiofemoral subluxation with increased varus angulation. However, this is difficult to prove, as bone quality is difficult to quantify on radiographs. In addition, the quality and integrity of the patient's soft tissue structures will undoubtedly have an effect on the degree of tibiofemoral subluxation present.

While the purposes of this study were achieved, it does have several limitations. The first limitation is that clinical follow-up to determine the significance of tibiofemoral subluxation in these patients must still be acquired. In addition, preoperative “stress” radiographs, to assess the correctability of tibiofemoral subluxation prior to performance of each patient's UKA were not available. Third, while the same protocol was used for obtaining each patient's preoperative and postoperative AP, standing, hip-to-ankle radiographs, these studies are still subject to rotational variations that may affect our measurements. Furthermore, these radiographs are not always performed on a routine basis both pre- and post-operatively, potentially limiting the applicability of our measurement method. However, routine application of these radiographs can be performed in the clinical setting.

Despite these limitations, this study remains important as it presents a novel method for measuring tibiofemoral subluxation that can be used in future studies. In addition, the degree of tibiofemoral subluxation present both preoperatively and postoperatively, and the amount of correction that can be expected in both medial and lateral UKAs is presented for the first time. While there remains uncertainty regarding the true significance of this measurement, this study represents our first step in trying to understand tibiofemoral subluxation and its ability to be corrected. Prior to subsequent studies, we felt it was crucial to 1) standardize the method in which tibiofemoral subluxation is measured, and 2) gain an understanding of the preoperative and postoperative values seen in patients undergoing unicompartmental knee arthroplasty. Future studies will be directed at determining both the impact of tibiofemoral subluxation on clinical results and outcomes, and developing surgical techniques that can improve tibiofemoral subluxation in unicondylar knee arthroplasty.

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