Stiffness after primary total knee arthroplasty: a radiographic analysis with a matched-control population

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ABSTRACT

Background:

The purposes of this study were (1) to evaluate standardized radiographic parameters in a population of patients who developed stiffness after primary total knee arthroplasty (TKA), and (2) to compare those to a matched control population.

Methods:

A retrospective review was performed to identify patients who required revision for stiffness after primary TKA. Patients with history of TKA revision or infection, as well as, those treated with isolated polyethylene exchange were excluded. Study patients were matched 1:1 with controls based on age, sex, body mass index (BMI). Radiographic measurements were performed by two blinded independent observers.

Results:

A total of 44 patients met the inclusion criteria. Thirty-one (70%) were females. Mean BMI was 33 kg/m^2 (19-58). Univariate odds ratios showed significance for patella baja (5.776; 0.025), increased anterior condylar offset ratio (ACO) (15.265; 0.000), increased anterior implant-cortex gap (5.067; 0.038), and increased percentage of patellar displacement (PPD) (6.476; 0.016). Multivariate regression analysis showed significance for ACO (18.307; 0.001) and PPD (9.338; 0.024). No significance was observed with respect to component alignment in the coronal or sagittal planes, posterior condylar offset ratio, patellar tilt, presence of heterotopic ossification, or posterior osteophyte formation. Intraclass correlation coefficients (ICCs) ranged from good to excellent (> 0.8) for all measurements performed.

Conclusions:

The restoration of the joint line and avoiding overstuffing the patellofemoral compartment are fundamental in preventing the development of postoperative stiffness. Poor mechanics of the patellofemoral compartment are significantly associated with the development of stiffness after primary TKA.

Key Words

primary TKA, stiffness, radiographic analysis, joint line height control group

INTRODUCTION

Knee stiffness is one of the most complex postoperative complications after total knee arthroplasty (TKA), and it represents a frustrating problem for both the surgeon and the patient.[1] The incidence of stiffness after TKA generally is low (1.3-5.3%) although its true incidence is difficult to estimate given the lack of a uniform definition.[2–4] It is, however, one of the most common causes of 90-day readmission and among the more common reasons for revision TKA.[5]

The development of stiffness after TKA has been attributed to multiple perioperative issues including technical difficulties during the surgical procedure, aggressive fibroblastic scar formation, poor patient adherence with rehabilitation because of a postoperative reaction or pain, infection, or mechanical issues related to the implant of the surrounding soft tissue.[1,2,6–9] Elevation of the joint line and overstuffing the patellofemoral (PF) compartment have been related to the development of stiffness after TKA;[1,2,6,8–11] however, to our knowledge, present supporting data are not robust.

The purposes of the present study were (1) to evaluate standardized radiographic parameters in a population of patients who developed stiffness after primary TKA, and (2) to compare those patients to a matched control population.

MATERIALS AND METHODS

After institutional review board approval, 559 consecutive revision arthroplasties performed by one of four arthroplasty surgeons (HJC, MSH, GRS, JAR) at a single institution

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between 2007 and 2014 were reviewed. Inclusion criteria were patients presenting with postoperative stiffness after primary TKA, available radiographs, and a minimum of 1-year follow-up (Figure 1). Patients with a history of previous TKA revision or infection and those treated with isolated polyethylene exchange were excluded (Figure 1). Stiffness was defined as the presence of one or more of the following criteria: (1) flexion contracture of 15 degrees or more, (2) less than 75 degrees of flexion, and/or (3) 90 degrees or less of arc of motion (AOM) with the chief complaint of limited range of motion and pain. The first two criteria were selected on the basis of gait analysis studies indicating an increased difficulty in walking with increasing flexion contracture and that 67 degrees of flexion is required for normal gait.[12] However, since this definition is purely objective, we decided to include a third criteria to incorporate the subjective component of stiffness and include patients presenting with 90 degrees or less of AOM and a chief complaint of limited range of motion and pain.

Patients who met inclusion and exclusion criteria were matched to controls who demonstrated greater than 90 degrees of AOM, full extension, and no complications 1 yr after primary TKA. Matching was performed one-to-one for age, gender, and body mass index (BMI).

A retrospective chart review was performed to identify relevant demographics (Table 1). Radiographic measurements (Figures 2 and 3) were calculated by two blinded observers (JMA and MB) using the Osirix Imaging Software (version 7.5.1; OsirixX MD, Bernex, Switzerland) and standardized radiographs according to the Modern Knee Society Radiographic Evaluation System and Methodology for Total Knee Arthroplasty.[13] These measurements included, coronal alignment (measured in anteroposterior [AP] weight-bearing views), sagittal alignment (measured in lateral [L] views), and patellar tilt angle (measured in patellofemoral views) (Figures 2 and 3). In addition, other radiographic parameters were evaluated, including the Insall-Salvati ratio[14,15] (L view), posterior condylar offset (PCO) ratio[16] (L view), anterior condylar offset (ACO) ratio (L view),[16] percentage of patellar displacement (PPD) (patella-femoral [PF] view),[13] heterotopic ossification (HO)[17] (AP and L views), femoral component (FC) notching[18] (L view), presence of a gap between the anterior flange

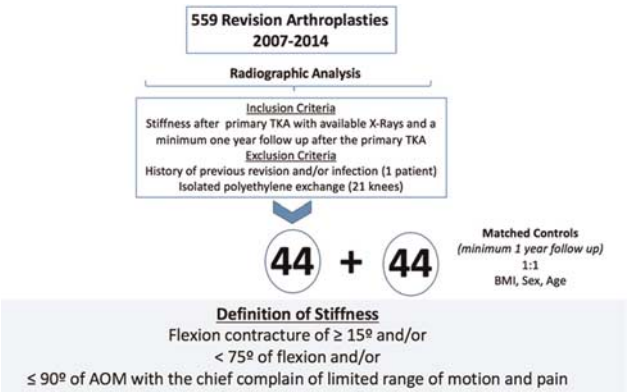

FIGURE 1. Inclusion and exclusion criteria. Definition of stiffness.

TABLE 1. Patient baseline demographics

	Stiff group	Control group
Study sample	44 knees	44 knees
Male knees	13 (29.5%)	13 (29.5%)
Female knees	31 (70.4%)	31 (70.4%)
Age (yr)	61 (77 to 33)	60 (77 to 33)
BMI (kg/m^2)	33 (19 to 58)	33 (19 to 59)
Mean follow-up (mo)	24 (12-48)	24 (12-48)

BMI, body mass index.

of the FC and the anterior femoral cortex (L view), presence of posterior osteophytes (L view) (Figures 2 and 3).

The ACO ratio was calculated based on the original description of the PCO ratio[16] as shown in Figure 3. The PPD was measured based on the distance from the center of the trochlea (represented as c1, d1 and e1 in Figure 2) to the center of the patella (midportion, represented as c1, d2 and e2 in Figure 2) divided by the total width of the patella in PF views (represented as c3, d3 and e3). Osteophytes when present were not considered part of the patella. HO was categorized based on the classification proposed by Rader *et al.*[17] as: Class 0, no HO; Class I, largest HO less than 5 cm^2 in lateral or AP radiographs or HOs in other knee regions; Class II, largest HO greater than 5 cm^2 in lateral or anteroposterior radiographs in the extensor apparatus or proximal femur; and Class III, largest HO greater than 5 cm^2 at the extensor apparatus and near the femur. Femoral component notching was graded according to the proposed classification of Gujarathi *et al.*[18] in the lateral view. The presence of a gap between the anterior flange of the femoral component and the anterior femoral cortex, as well as the presence of posterior osteophytes were categorized as present or not present.

Data were collected in Excel and analyzed using SPSS for Windows statistical software (version 18.0; SPSS, Chicago, Illinois). Continuous variables were analyzed descriptively using means, standard deviations, and range. Mean deviations as well as 95% confidence intervals were calculated to assist interpretation. Categorical variables, were described using frequency distributions indicating absolute and relative frequencies. Intraclass Correlation Coefficients (ICC) were used to assess the interrater reliability of the measurements. Paired *t* tests were used for continuous variables to determine statistical significance between groups. Categorical variables were compared using a chi-square test for association. Multivariate regression analysis also was conducted to identify factors predictive of stiff TKA. For all analyses, a significance level of 5% was applied.

RESULTS

The study groups involved 44 knees, of which, 31 were in women and 13 were in men (Table 1). The mean age of the stiffness cohort was 61 yr (range, 77-33 yr) at the time of the index procedure and 60 yr (77-33 yr) in the control group. The diagnosis before primary TKA was osteoarthritis (OA) in all knees (100%) in both groups. The initial range of motion of the arthritic knees was not known in the majority of the patients (80%) given the referral nature of our practice.

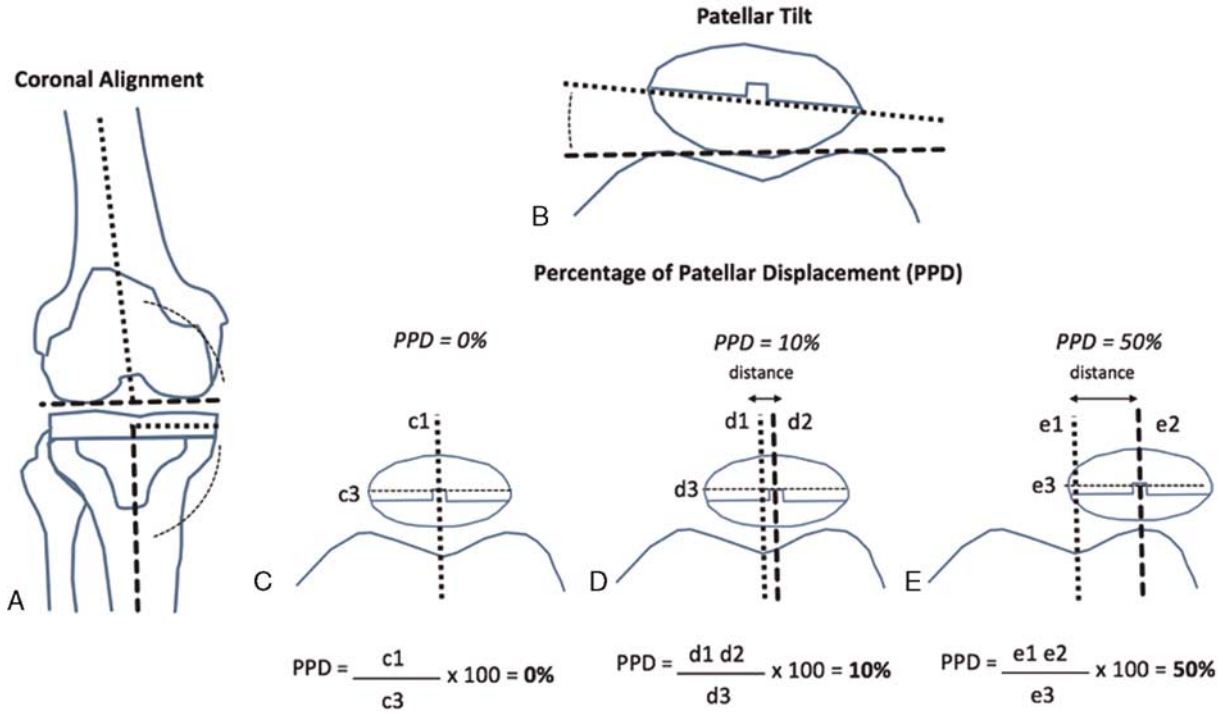

FIGURE 2. **(A)** Coronal alignment of the femoral and tibial components. **(B)** Patellar tilt. **(C)** Percentage of patellar displacement.

Intraclass correlation coefficients (ICCs) were greater than 0.8 for all radiographic measurements performed in both groups, demonstrating good-to-excellent interobserver agreement (Table 2). Univariate odds ratios showed patients who developed stiffness were significantly more likely to have patella baja (5.776; 0.025), increased anterior condylar offset ratio (ACO) (15.265; 0.000), increased femoral component anterior cortex gap (5.067; 0.038), and increased PPD (6.476; 0.016) (Table 2).

Multivariate regression analysis demonstrated that an increased ACO ratio (18.307; 0.001) and an increased PPD (9.338; 0.024) were significantly associated with stiffness. No

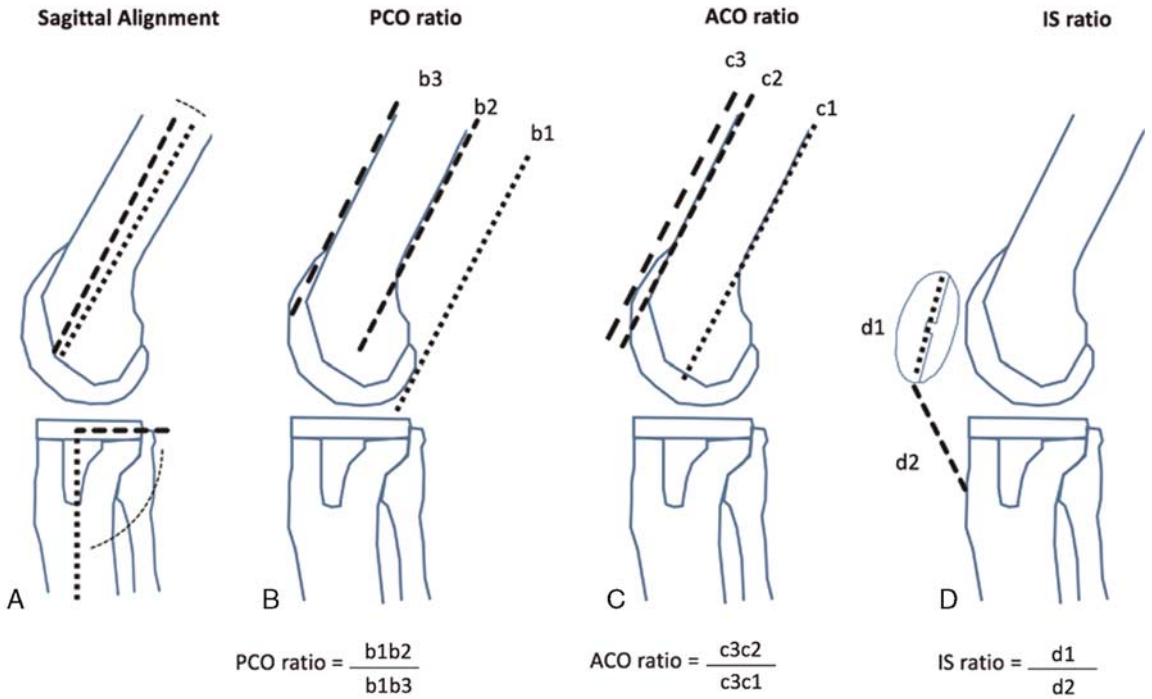

FIGURE 3. **(A)** Sagittal alignment of the femoral and tibial components. **(B)** Posterior condylar offset ratio. **(C)** Anterior condylar offset ratio. **(D)** Insall-Salvati ratio.

significant differences were observed with respect to component alignment in the coronal or sagittal plane, posterior condylar offset ratio, patellar tilt, presence of HO and posterior osteophyte formation.

DISCUSSION

The aims of this study were to quantify particular radiographic parameters in a population of patients who required revision for stiffness after primary TKA, and to compare those to a match control population of patients with no complications 1 yr after a primary TKA. Our results demonstrated significant differences between groups with regards to the ACO ratio (higher in the stiffness group), patellar height (higher prevalence of patella baja in the stiffness group), presence of implant-cortex gap (higher prevalence in the stiffness group) and percentage of patellar displacement (higher in the stiffness group). All these factors seem to indicate that the presence of a patella baja, as well as, the overstuffing of the patellofemoral compartment are significantly related to the development of stiffness after TKA.

Development of stiffness after primary TKA has been related to multiple factors[1,2,6,8–11] that include the presence of a reduced preoperative knee range of motion, history of prior knee surgery, etiology of osteoarthritis, incorrect positioning or oversized components, and an incorrect gap balancing. To our knowledge this is the first study evaluating specific radiographic parameters in a population of patients with stiffness and in a matched control group. Gandhi *et al.*,[8] however, conducted a similar matched-control study to evaluate certain predictive factors for stiffness, and they reported a significant correlation between postoperative stiffness and a decreased patellar height. Our results (79.5% of the patients in the stiffness group had patella baja) are similar to those reported by Gandhi *et al.*,[8] suggesting that the presence of a patella baja is significantly related to a decrease ROM after primary TKA.

In addition, our results suggest that overstuffing the patellofemoral compartment (increased ACO ratio, higher prevalence of anterior implant cortex gap, and higher percentage of patellar displacement) also is significantly related to the development of stiffness after TKA. This article also provides two additional radiographic measurements: the ACO ratio and the PPD. The ACO ratio was calculated based on the original description of the PCO ratio[16,19] (Figure 3C), and it showed a high to excellent correlation between both observers in all measurements performed (94.74%). The PPD also presented a high to excellent correlation between observers in all measurements performed (89.60%).

It is well known that patellar height plays an important role in the final ROM of patients after TKA.[4,8,11,20] A low sitting patella can be the result of joint line elevation or scarring and subsequent shortening of the infrapatellar tendon in patients with limited ROM. We measured patellar height based on the Insall-Salvati ratio.[14] Therefore, we were not able to determine

TABLE 2. Radiographic measurements results

	Stiffness	Control	*Correlation*	*P*
Number of knees	44	44		
AP view				
FC alignment	94.20° (SD 7.06)	95.66° (SD 7.05)	84.84	*0.371*
TC	88.14° (SD 6.50)	88.56° (SD 1.67)	79.92	*0.071*
HO				
0.	17	27		
1.	19	11		
2.	6	5		
3.	2	0		*0.447*
Lateral view				
FC	10.16° (SD 3.34)	10.95° (SD 4.40)	86.79	*0.259*
Tibial slope	86.66° (SD 6.50)	86.51° (SD 2.08)	92.34	*0.846*
Patella baja	35 (79.5 %)	9 (20.4%)	90.23	***0.025***
PCO ratio	0.50 (SD 0.07)	0.52 (SD 0.06)	97.21	*0.176*
ACO ratio	0.20 (SD 0.06)	0.15 (SD 0.05)	94.74	***0.000***
FC-AC gap	20 (45.4%)	11 (25%)	86.40	***0.038***
Post. osteoph.	14 (31.8%)	14 (31.8%)	100	*1.000*
FC notching				
0.	19	21		
1.	16	19		
2.	5	3		
3.	4	1		
4.	0	0		*0.902*
PF view				
Patellar tilt angle	5.48° (SD 5.46)	3.71° (SD 3.35)	83.18	*0.122*
PPD	9.6% (SD 8.4)	5.7% (SD 4.5)	89.60	***0.016***

AC, anterior cortex; ACO, anterior condylar offset; Ant, anterior; AP, anteroposterior; FC, femoral component; TC, tibial component; HO, heterotopic ossification; PCO, posterior condylar offset; PF, patellofemoral; Post, posterior; PPD, percentage of patellar displacement.
Bold denotes statistical significance.

if this finding was the result of the joint elevation or secondary to the scarring of the patellar tendon.

In addition, several groups have discussed stiffness related to overstuffing the patellofemoral compartment;[1,9,20] however, no specific data have been published in that regard. The stuffing of the patellofemoral joint happens when an insufficient patellofemoral space is created for the size of the implants inserted. Such over-replacement can lead to reduced flexion after TKA and thus to the development of stiffness. Overstuffing of the patellofemoral joint can be caused by anteriorization of the femoral component or under-resection of the patella, or both, and creating a thicker patellar bone composite,[10] or choosing a femoral component that is larger than the natural femur. An oversized femoral component not only affects patellofemoral kinematics but also leads to a narrow flexion space further affecting knee motion.[9] This argument may be partly responsible for the higher PPD observed in the stiffness group. The stresses of the patella in an overstuffed compartment could create forces that tend to displace it laterally. For all these reasons we believe that the restoration of the patellofemoral joint should play an important role during primary TKA.

When confronting patients presenting with postoperative stiffness after primary TKA, one should carefully evaluate all possible factors contributing to that condition to determine the appropriate course of treatment. Therefore, if the reason for stiffness is believed to be caused by component malposition, patella baja, oversized femoral component, or overstuffing of the patellofemoral compartment (increased ACO ratio, presence of anterior implant cortex gap, and higher percentage of patellar displacement) then the revision of such components could result in an increase in ROM.[3,21,22] However, further radiographic analysis is needed to evaluate whether the restoration of those parameters result in better clinical and functional outcomes.

The limitations of this study include that it is a retrospective radiographic review and many (80%) of the index TKAs were referred to the senior surgeons for revision, therefore preoperative radiographs were not available for evaluation in such cases. For that reason, we used the patellar position as a surrogate for joint line restoration. Patellar thickness was not evaluated and may have influenced the restoration of the anterior compartment and affected postoperative knee motion. Several other clinical factors contributing to the development of stiffness after TKA, such as pre-TKA ROM, patient compliance with their postoperative rehabilitation, and pain management were not taken into consideration. However, we do not believe that these shortcomings undermine the important findings of this study.

In summary, the restoration of the joint line, as well, as avoiding overstuffing the patellofemoral compartment are fundamental in preventing the development of postoperative stiffness. Poor mechanics of the patellofemoral compartment are significantly associated with the development of stiffness after primary TKA; therefore, treating these problems may be important to achieving a successful result.

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