Spontaneous Osteonecrosis/Subchondral Insufficiency Fractures of the Knee

High Rates of Conversion to Surgical Treatment and Arthroplasty

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Background: Spontaneous osteonecrosis of the knee has recently been termed subchondral insufficiency fracture of the knee (SIFK) to appropriately recognize the etiology of mechanical overloading of the subchondral bone. The purpose of this study was to assess clinical outcomes of SIFK based on progression to surgical treatment and arthroplasty, and to evaluate the risk factors that increase the progression to arthroplasty.

Methods: A retrospective review was performed on patients with a diagnosis of SIFK, as confirmed with use of magnetic resonance images (MRIs). Baseline and final radiographs were reviewed. Baseline MRIs were also reviewed for injury characteristics. Failure was defined as progression to surgical treatment or conversion to arthroplasty.

Results: Two hundred twenty-three patients (71% female) with a mean age of 65.1 years were included. SIFK affected 154 femora (69%) and 123 tibiae (55%), with medial compartment involvement in 198 knees (89%); 74% of medial menisci had root or radial tears, with a mean extrusion of 3.6 mm. Varus malalignment was identified in 54 (69%) of 78 knees. Seventy-six (34%) of all patients progressed to surgical intervention at 2.7 years, and 66 (30%) underwent arthroplasty at 3.0 years. The rates of conversion to surgical intervention and arthroplasty increased to 47% (37 of 79; $p = 0.04$) and 37% (29 of 79; $p = 0.09$), respectively, in patients with >5 years of follow-up. The 10-year survival rate free of arthroplasty for patients with SIFK on the medial femoral condyle ($p < 0.01$), SIFK on the medial tibial plateau ($p < 0.01$), medial meniscal extrusion ($p = 0.01$), varus alignment ($p = 0.02$), and older age (per year older; $p = 0.003$) was significantly higher than the survival rates of those without each respective condition.

Conclusions: Subchondral insufficiency fractures predominantly involve the medial compartment of the knee and commonly present with medial meniscal root and radial tears. Approximately one-third of patients progressed to total knee arthroplasty. Baseline arthritis, older age, location of the insufficiency fracture on both the medial femoral condyle and medial tibial plateau, meniscal extrusion, and varus malalignment were all associated with progression to arthroplasty.

Level of Evidence: Prognostic Level IV. See Instructions for Authors for a complete description of levels of evidence.

Previous studies on spontaneous osteonecrosis of the knee reported on heterogeneous patient cohorts[1]. Newer studies have postulated that primary spontaneous osteonecrosis of the knee in older patients may occur as a result of mechanical overloading of the subchondral bone in the setting of meniscal tears and concomitant meniscal extrusion[2-6]. Therefore, a more appropriate term for the condition may be subchondral insufficiency fracture of the knee (SIFK)[4].

Multiple studies have explored the progression of SIFK and conversion to surgical treatment, but most are limited by a small sample size and are underpowered to identify independent risk factors[7-9]. Furthermore, short follow-up periods did not allow for the accurate assessment of conversion to operative management or long-term rates of osteoarthritis[10,11].

The purposes of the present study were to (1) assess the clinical outcomes of SIFK based on progression to surgical treatment and arthroplasty and (2) evaluate risk factors that increase the progression to arthroplasty in a large retrospective cohort. We hypothesized that patients with increased malalignment and increased meniscal extrusion

Disclosure: The authors indicated that no external funding was received for any aspect of this work. On the **Disclosure of Potential Conflicts of Interest** forms, *which are provided with the online version of the article*, one or more of the authors checked "yes" to indicate that the author had a relevant financial relationship in the biomedical arena outside the submitted work (http://links.lww.com/JBJS/F805).

would have higher rates of arthroplasty at the time of the latest follow-up.

Materials and Methods

We performed a retrospective search of our institutional radiology database after obtaining approval from the institutional review board (ID# 15-000601). The terms "subchondral insufficiency fracture," "SIFK," "spontaneous osteonecrosis," "SPONK," and "SONK" were queried for the years 2005 to 2017. Inclusion criteria consisted of patients with subchondral insufficiency fracture about the knee (distal femoral and/or proximal tibial) as verified on magnetic resonance images (MRIs). Patients with <1-year follow-up, secondary osteonecrosis (defined as osteonecrosis as a result of medical treatment—e.g., radiation or steroid treatment), and evidence of a prior surgical procedure on MRIs, radiographs, and/or chart review were excluded from the study. Patients who converted to operative treatment prior to the 1-year follow-up were included in all analyses. All radiographs and MRIs were reviewed by 2 independent reviewers (surgeons) to assess characteristics such as SIFK location, subchondral edema presence and location, meniscal tear type, ligamentous injury, and Kellgren-Lawrence (K-L) grade[12]. Cases in which lesions were present at multiple locations were noted as such (e.g., 1 lesion on the medial femoral condyle and 1 on the medial tibial plateau would have been represented as "lesion on MFC and MT"). Limb alignment was calculated with use of full-length, hip-to-ankle, weight-bearing radiographs. Patients without full-length radiographs were excluded from alignment calculation. Anatomic alignment was calculated with use of the tibiofemoral angle (femoral shaft-tibial shaft angle) according to the circle method[13]. A normal value of 6° and standard deviation of 2° were utilized for the femoral shaft-tibial shaft angle, with values of <4° considered varus and >8° considered valgus[14]. Overall, 35% of the radiographs (78 of 223) were full-length radiographs, and these patients were included in statistical analyses involving limb alignment. Patient and surgical characteristics were obtained through retrospective chart review.

All patients had MRIs available. Meniscal tears were classified as root, radial, other, or none. Root tears were defined as those with a complete radial tear or complete avulsion of the meniscus within 9 mm of the root attachment (Fig. 1)[15]. Complex tears with loss of hoop stresses, a predominant radial component, and meniscal extrusion on MRI were classified as radial. Displacement of >3 mm on the mid-coronal plane was classified as an extrusion[16]. Vertical, complex, and horizontal meniscal tears that did not satisfy the aforementioned definitions were classified as "other" because of the rarity of such instances. An insufficiency fracture was defined as a low-signal-intensity focus beneath the articular surface in the weight-bearing area of the tibiofemoral compartment on T1-weighted images and a central focal linear subchondral low-signal-intensity or focal subchondral bone plate impaction with marked surrounding bone marrow edema on fat-suppressed T2-weighted images (Fig. 1)[17].

Patient-reported outcomes in the form of Tegner[18] and Knee Society scores[19] were obtained at patient presentation (initial) and at the preoperative time point (final) if the patient progressed to any surgical management.

Statistical Analysis

Continuous variables were reported as the mean and standard deviation, with the mean weighted for sample size. Categorical variables were reported as percentages. Differences between continuous variables were evaluated with use of 2-tailed Mann-Whitney U tests. Differences between categorical variables were evaluated with use of a chi-square analysis. Kaplan-Meier curves were utilized to evaluate risk factors for progression to arthroplasty. Differences between survival curves were assessed with use of the log-rank test. Hazard ratios (HRs) were calculated with use of a Cox proportional-hazards model. All data

Fig. 1

Fig. 1-A Coronal T2-weighted MRI showing a full-thickness tear of the posterior root of the medial meniscus. **Fig. 1-B** Coronal T2-weighted MRI showing a subchondral insufficiency fracture of the medial femoral condyle. **Fig. 1-C** Sagittal T1-weighted MRI showing a subchondral insufficiency fracture of the medial femoral condyle.

TABLE I Patient Characteristics

Age* *(yr)*	65.1 ± 10.2
Sex†	
Male	29%
Female	71%
Body mass index* *(kg/m²)*	32.3 ± 7.1
Side†	
Right	46%
Left	54%
K-L grade†	
1	17%
2	51%
3	26%
4	6%
Varus malalignment* *(°)*	1.9 ± 2.8

*The values are given as the mean and standard deviation. †The values are given as the percentage of patients in the cohort.

were analyzed with use of JMP software (version 14.0.0; SAS Institute).

Power Analysis

An a priori power analysis for the log-rank test was performed to determine the sample size by use of a 2-tailed hypothesis test at an alpha level of 0.05, a power of 0.8, and a sample proportion of 1:1 in the cohorts. For a survival analysis with an HR of 1.5, a total of 191 patients would be needed, whereas only 65 patients would be needed for an HR of 2[20].

Results

Patient Characteristics

A total of 223 patients (71% female) with SIFK verified on MRIs, a mean age of 65.1 ± 10.2 years, and a mean body mass index of 32.3 ± 7.1 kg/m² were included (Table I). The mean follow-up was 4.4 years (range, 1.0 to 10.9 years). The mean anatomic alignment was 1.9° ± 2.8°, and 152 knees (68%) were radiographically classified as K-L grade 1 or 2 at the time of the initial presentation. One hundred and twenty-one patients (54%) had an unknown mechanism of injury (i.e., they could not recall how the injury may have occurred), 58 (26%) had a hyperflexion event, 31 (14%) had a twisting event, and 13 (6%) were injured while running and/or jumping. The mean duration of symptoms was 8.0 months (range, 0 to 240 months) at the time of presentation. All 223 patients (100%) had knee-joint pain, with 29 (13%) reporting subjective instability and 25 (11%) reporting mechanical symptoms (catching, clicking, locking, etc.). One hundred and eighty-seven patients (84%) were treated with weight-bearing modification with assistive devices (either partial or non-weight-bearing for a period of time), 174 (78%) were treated with unloader braces, and 154 (69%) received an injection of either corticosteroids or viscosupplementation.

Imaging Characteristics

Among the 223 patients, SIFK affected 154 (69%) of the femora and 123 (55%) of the tibiae. The medial femoral condyle was involved in 129 knees (58%) and the medial tibial plateau was involved in 107 knees (48%) (Table II). SIFK in either both femoral condyles or both tibial condyles was uncommon (4% and 2%, respectively). Insufficiency fractures were located in both the femur and tibia in 51 knees (23%). The medial compartment had an insufficiency fracture in 198 knees (89%), and the lateral compartment was affected in only 33 knees (15%). Subchondral edema was present in 221 knees (99%) (Table II).

Meniscal tears were identified in 187 knees (84%) on MRIs. The medial aspect of the meniscus was torn in 172 knees (77%), with the majority being root and radial tears (Fig. 2-A). The lateral aspect of the meniscus was torn in 33 knees (15%), divided evenly between root and radial tears (Fig. 2-B). The mean medial meniscal extrusion was 3.6 ± 2.3 mm and the mean lateral meniscal extrusion was 0.3 ± 1.1 mm across all patients. One hundred and fifty-one medial menisci (68%) had extrusion of >3 mm, whereas only 10 lateral menisci (4%) had a similar finding. When isolating meniscal tears with radial and/or root tears, the mean medial meniscal extrusion was 4.6 ± 1.7 mm and the mean lateral meniscal extrusion was 1.9 ± 2.2 mm.

Of the 79 knees with long-leg radiographs, anatomic alignment was normal in 19 (24%), varus in 54 (68%), and valgus in 6 (8%). Within this subset, varus knees had an increased level of SIFK on the medial femoral condyle compared with normal and valgus knees (73% compared with 50% and 12%, respectively; $p = 0.001$). This was not the case for SIFK on the medial tibial plateau ($p = 0.83$). Valgus knees had significantly more SIFK on the lateral tibial plateau compared with normal and varus-aligned knees (44% compared with 0%

TABLE II Distribution of Patients with Femoral and Tibial Subchondral Edema and SIFK*

	SE	SIFK
Femur		
MFC	61.0%	56.2%
LFC	7.2%	7.2%
Both MFC and LFC	8.4%	3.6%
None	23.3%	32.9%
Tibia		
MT	56.6%	47.6%
LT	6.8%	5.2%
Both MT and LT	12.0%	2.0%
None	24.5%	45.1%

*The values are given as the percentage of patients. SE = subchondral edema, MFC = medial femoral condyle, LFC = lateral femoral condyle, MT = medial tibial plateau, and LT = lateral tibial plateau.

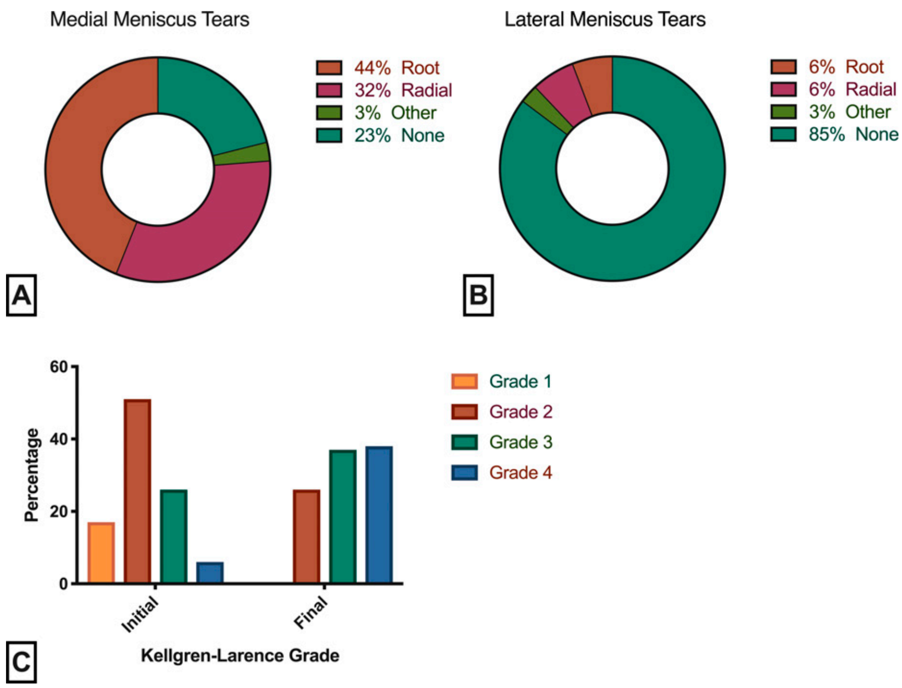

Fig. 2
Distribution of types of medial (**Fig. 2-A**) and lateral (**Fig. 2-B**) meniscal tears and of K-L grade (**Fig. 2-C**).

and 0%, respectively; p = 0.002), although this relationship was not true for SIFK on the lateral femoral condyle (p = 0.19).

Partial or full-thickness tears of the other ligaments were uncommon among the 223 knees, with 13 occurring in the anterior cruciate ligament (6%), 4 in the posterior cruciate ligament (2%), 4 in the medial collateral ligament (2%), and 2 in the lateral collateral ligament (1%).

Outcomes

None of the patients had a K-L grade of 1 at the time of the latest radiographs, whereas 165 patients (74%) had a K-L grade of 3 (37%) or 4 (38%) (Fig. 2-C). From initial to latest radiographs, 77 knees (35%) did not have a change in K-L grade, whereas 99 (44%) had a change in K-L grade of 1 level, 43 (19%) had a change in K-L grade of 2 levels, and 4 (2%) had a change in K-L grade of 3 levels.

Eighty-nine patients (40%) had an increase in K-L grade of 2 levels, had a K-L grade of 4, or had undergone arthroplasty at the time of the latest follow-up. A subanalysis of patients with a minimum follow-up of 5 years revealed that 71 knees (32%) had a change in K-L grade of 2 or more levels. The rate of arthroplasty was not significantly different in patients with >5 years of follow-up compared with the entire cohort (37% compared with 30%; p = 0.09), even though the rate of conversion to surgical treatment increased from 34% (27 of 79) to 47% (37 of 79) (p = 0.04). In this subanalysis, 39 patients (49%) had an increase in K-L grade of 2 levels, had a K-L grade of 4, or had undergone arthroplasty at the time of the latest follow-up.

Seventy-six patients (34%) underwent initial surgical intervention at a mean of 2.7 ± 2.7 years from the time of the initial diagnosis. The most common initial surgical procedure was total knee arthroplasty (22%; 50 of 223), followed by partial meniscectomy (8%; 18 of 223), unicondylar knee arthroplasty (2%; 4 of 223), and root repair (2%; 4 of 223). The rates of survival free from surgical intervention at 1 year, 5 years, and 10 years were 67%, 61%, and 58%, respectively (Fig. 3-A).

Sixty-six patients (30%) eventually progressed to arthroplasty at a mean of 3.0 ± 2.8 years, which corresponded with the rates of survival free from arthroplasty at 1, 5, and 10 years of 76%, 68%, and 66%, respectively (Fig. 3-B). Eighty-seven percent of all patients who underwent conversion to surgical treatment and 79% of all patients who underwent conversion to arthroplasty had the procedure within 1 year.

In patients who had "kissing" lesions (i.e., lesions on the medial femoral condyle and medial tibial plateau at the same time or the lateral femoral condyle and lateral tibial plateau at the same time) had an arthroplasty rate of 54% (24 of 44) and an operative rate of 57% (25 of 44), both of which were significantly higher than the overall rates for the cohort (p = 0.001 and p = 0.006, respectively).

The mean initial Knee Society score across the cohort was 63.5 ± 11.2. Among patients who ultimately underwent conversion to surgical treatment, the initial Knee Society score (59.8 ± 8.8) did not significantly differ from the latest Knee Society score (54.8 ± 8.0; p = 0.15). In patients who continued nonoperative treatment, the Knee Society score at the time of presentation (64.3 ± 11.7) was also similar to the latest Knee Society score (63.2 ±11.1; p = 0.78).

Risk Factor Analysis

Baseline K-L grades had a significant effect on survival (Fig. 4-A, Table III). Survivorship for K-L grade-4 knees was

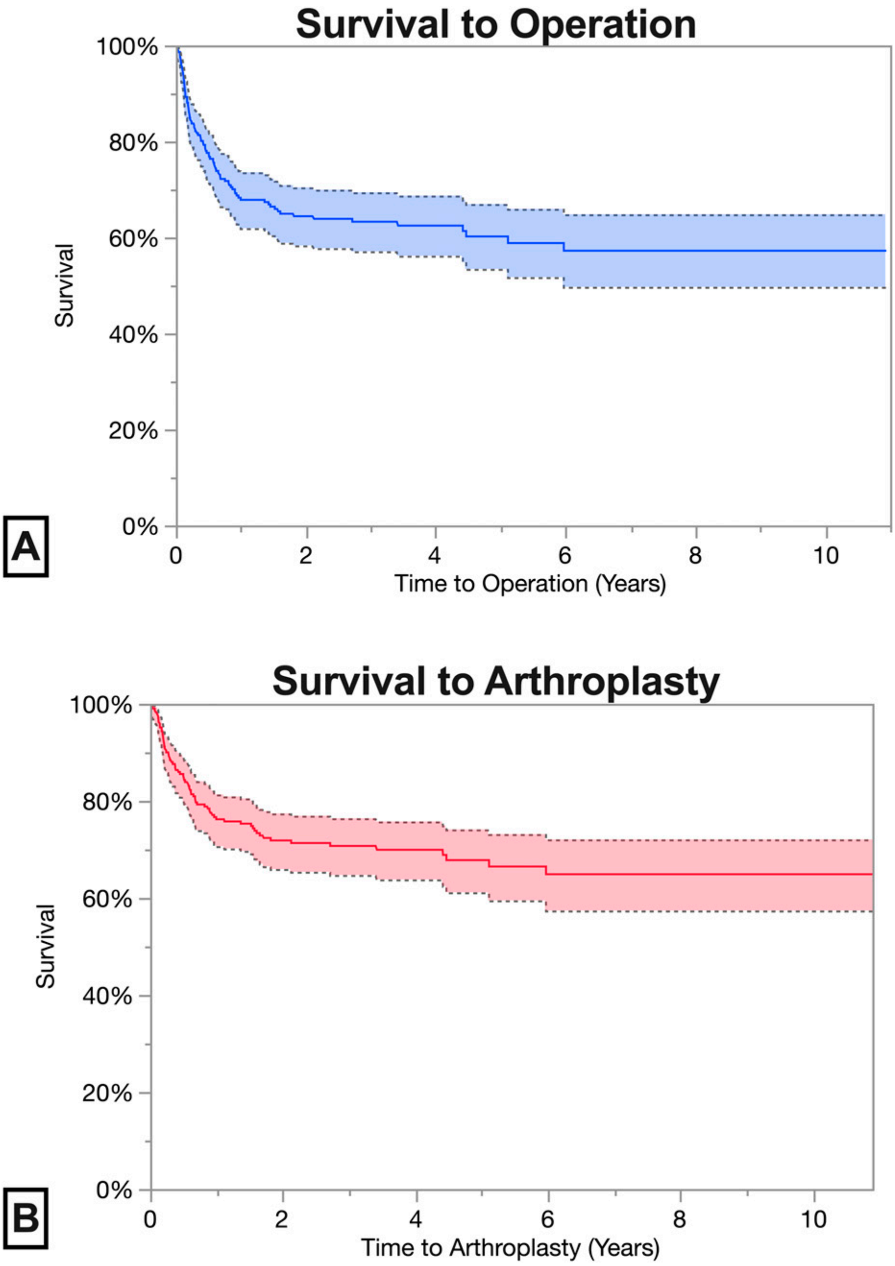

Fig. 3

Kaplan-Meier survival curves for conversion to surgical treatment (**Fig. 3-A**) and arthroplasty (**Fig. 3-B**). Shaded areas represent the 95% CI.

significantly inferior compared with K-L grade 1, K-L grade 2, and K-L grade 3. Survivorship was not significantly different in all other K-L grade comparisons (Table III).

The location of the SIFK also had an impact on survivorship. Patients with SIFK on the medial femoral condyle had a >2-fold lower survivorship free from arthroplasty compared with those with SIFK at another location (HR, 2.6; 95% confidence interval [CI], 1.4 to 4.6). Similarly, the 2-year and 10-year rates of survivorship were 68% and 60%, respectively, for patients with SIFK on the medial tibial plateau compared with 86% and 81%, respectively, for patients with SIFK at another location (Figs. 4-B and 4-C, Table III). The comparison between Kaplan-Meier curves was significant for the log-rank test (p = 0.002) but was not significant for the Cox proportional-hazards test (HR, 1.2; 95% CI, 0.7 to 1.9). Patients with SIFK on the lateral femoral condyle and lateral tibial plateau did not have significantly reduced survivorship compared with patients who had SIFK at another location (p = 0.51 and p = 0.70, respectively). The 2-year and 10-year rates of survivorship for patients with SIFK on the lateral femoral condyle and the lateral tibial plateau were the same (72% at each time point for both curves).

The 160 patients with 161 meniscal extrusions had significantly lower survivorship compared with those who did

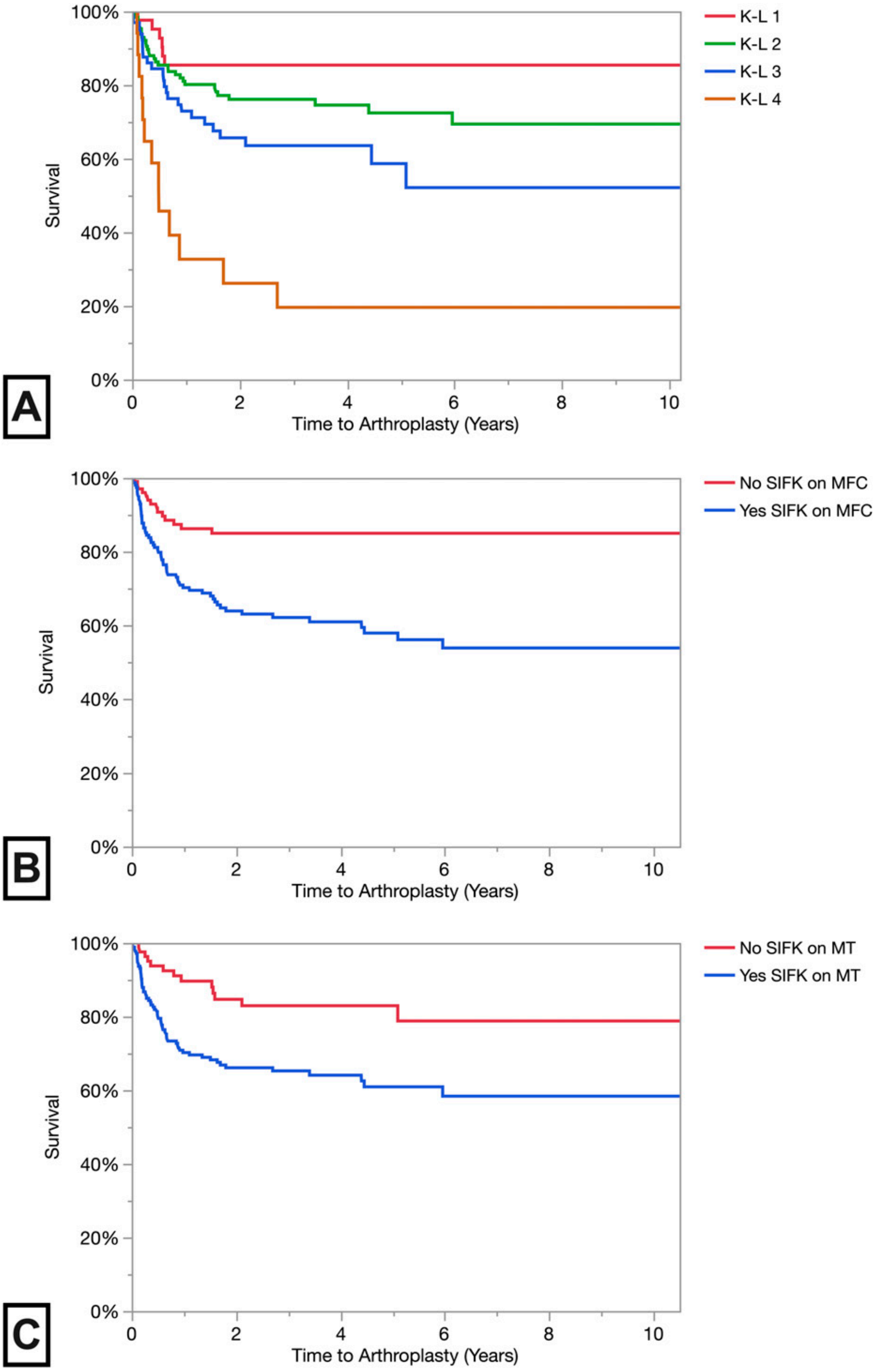

Fig. 4
Kaplan-Meier survival curves by K-L grade (**Fig. 4-A**) and SIFK on the medial femoral condyle (MFC) (**Fig. 4-B**) and medial tibial plateau (MT) (**Fig. 4-C**).

not. Survivorship for patients with medial meniscal extrusion (HR, 2.8; 95% CI, 1.5 to 5.4) and lateral meniscal extrusion (HR, 2.8; 95% CI, 1.2 to 6.4) was almost threefold less compared with compared with those who did not have meniscal extrusion at that location. Patients with varus anatomical malalignment had significantly lower survivorship free from arthroplasty compared with those who had normal alignment (HR, 4.6; 95% CI, 1.2 to 17.2), but not when compared with those with valgus malalignment (p = 0.38). When assessed in a continuous manner, each degree of varus and each degree of increased medial meniscal extrusion were associated with an increased risk of progression to arthroplasty (HR, 1.14 per degree of varus; p = 0.03; and HR, 1.29 per degree of extrusion; p = 0.002, respectively).

TABLE III Progression to Arthroplasty*

	HR (95% CI)	P Value
K-L grade		
4:4	1.0 (reference)	
4:1	8.1 (3.0, 22.0)	**<0.001**
4:2	4.8 (2.4, 9.5)	**<0.001**
4:3	3.3 (1.6, 6.9)	**0.002**
SIFK on MFC		
MFC not involved	1.0 (reference)	
MFC involved	2.6 (1.4, 4.6)	**0.002**
SIFK on LFC		
LFC not involved	1.0 (reference)	
LFC involved	0.86 (0.4, 2.0)	0.73
SIFK on MT		
MT not involved	1.0 (reference)	
MT involved	1.2 (0.7, 1.9)	0.56
SIFK on LT		
LT not involved	1.0 (reference)	
LT involved	0.93 (0.3, 2.6)	0.89
Medial meniscal extrusion		
Not extruded	1.0 (reference)	
Extruded	2.8 (1.5, 5.4)	**0.002**
Lateral meniscal extrusion		
Not extruded	1.0 (reference)	
Extruded	2.8 (1.2, 6.4)	**0.02**
Alignment		
Normal	1.0 (reference)	
Varus	3.7 (1.1, 12.1)	**0.01**
Valgus	2.4 (0.4, 14.5)	0.34
Age		
<65 years	1.0 (reference)	
≥65 years	2.1 (1.3, 3.6)	**0.005**
Body mass index		
<30 kg/m²	1.0 (reference)	
>30 kg/m²	1.1 (0.7, 1.8)	0.62

*MFC = medial femoral condyle, LFC = lateral femoral condyle, MT = medial tibial plateau, and LT = lateral tibial plateau. Bolded p values indicate significance.

Obesity (body mass index >30 kg/m²; p = 0.62) and sex (p = 0.65) did not have significant impacts on progression to arthroplasty; however, older age (≥65 years) was associated with an increased progression to arthroplasty (HR, 2.1; 95% CI, 1.3 to 3.6 (Table III).

Overall, the 10-year survival rate free of arthroplasty for patients with SIFK on the medial femoral condyle (p < 0.01), SIFK on the medial tibial plateau (p < 0.01), medial meniscal extrusion (p = 0.01), varus alignment (p = 0.02), and older age (per year older; p = 0.003) was significantly higher than the survival rates of those without each respective condition.

Discussion

In the present study of 223 patients with a mean follow-up of 4.4 years, medial meniscal radial and root tears were found to be contributing factors for SIFK. The rates of conversion to surgical treatment (34%) and arthroplasty (30%) were high, with a rate of conversion to operative treatment of nearly 50% among patients with >5 years of follow-up. Baseline K-L grade, increasing age, SIFK location on the medial femoral condyle and/or medial tibial plateau, and meniscal extrusion were found to be significant risk factors for progression to arthroplasty.

The most common location for SIFK in this cohort was the medial femoral condyle, and the most common location for a meniscal tear was the medial side with root (44%; 98 of 223) and radial (32%; 72 of 223) lesions being most prevalent. Recent studies have found similar rates of meniscal involvement in knees with SIFK, with Nelson et al. reporting a rate of meniscal tears of 88% (20 of 32)[21]. In 2 studies of patients with SIFK of the medial femoral condyle, Robertson et al. and Yamagami et al. reported a medial meniscal posterior root tear in 24 (80%) of 30 patients and 28 (62%) of 45 patients, respectively, which are similar to the proportion observed in the present study[5,22].

The rates of conversion to surgical treatment and arthroplasty in the present study were 34% (76 of 223) and 30% (66 of 223), respectively. In a study of 73 patients, Plett et al. reported that the medial femoral condyle was involved in 89% of cases (65 of 73) and that 94% of knees (64 of 68) had ipsilateral meniscal injury[23]. The authors also reported an arthroplasty rate of 24% (11 of 46), although the study had limitations—particularly that follow-up was only available for 46 of the 73 patients. Furthermore, the mean follow-up for the included patients who progressed radiographically was <2 years (22.5 months)[23].

Additional studies have also implicated various risk factors for progression of SIFK to surgical treatment and arthroplasty. In the present study, increased preoperative K-L grade, older age, varus malalignment, SIFK on the medial femoral condyle and medial tibial plateau, and medial or lateral meniscal extrusion (>3 mm) were associated with increased rates of conversion to arthroplasty. In a study evaluating the outcomes of medial meniscal posterior horn root tears, higher baseline K-L grade was associated with an increased rate of arthroplasty[24]. A case-control study evaluating partial meniscectomy for degenerative medial meniscal root tears revealed that varus-aligned knees had a twofold greater risk of progression of radiographic arthritis and arthroplasty at 2 years postoperatively[25].

The literature is limited in reporting the presence of SIFK on the medial femoral condyle and medial tibial plateau as risk factors for progression to arthroplasty compared with SIFK in other anatomic locations. The results of the present study show that injuries to the medial femoral condyle and medial tibial plateau are risk factors for progression to arthroplasty. This finding may be because there were a high number of patients with varus malalignment and a high number of patients with a medial meniscal tear, which, in combination, would substantially increase the focal stresses on the medial compartment[10,16,24]. In a study evaluating the location of SIFK on the femoral condyle as a risk factor for progression to arthroplasty, there was no difference between patients with SIFK on the medial femoral condyle compared with the lateral femoral condyle (p = 0.24), although the study was likely underpowered because only 46 patients were included for clinical follow-up[23]. Additionally, that study did not include lesions on the tibia.

Knees with meniscal extrusion (both medially and laterally) had a significantly higher rate of progression to knee arthroplasty than those without. Recent studies have postulated that meniscal extrusion causes increased focal contact stresses at the tibiofemoral interface, resulting in increased arthrosis and need for arthroplasty[1,4,16,26]. In a 2018 study evaluating operatively managed medial meniscal posterior horn tears, meniscal extrusion was associated with a significantly higher rate of arthritis at the time of the latest follow-up, with a progression of at least 1 K-L grade in 100% of the patients with meniscal extrusion compared with only 57% of the patients without extrusion[27]. Teichtahl et al. reported that patients with a K-L grade of 3 or 4 in addition to medial meniscal extrusion (odds ratio [OR] = 1.4; p = 0.03) and lateral meniscal extrusion (OR = 1.8; p = 0.01) had increased odds of arthritis progression[28]. This finding also held true for risk of arthroplasty (medial meniscal extrusion, OR = 1.8; p = 0.001; and lateral meniscal extrusion, OR = 1.6; p = 0.04)[28].

Strengths and Limitations

The present study had several strengths. The study included a relatively large cohort of patients with SIFK, which resulted in increased power compared with previous studies. The longer mean follow-up (mean, 4.4 years; maximum, >10 years) and exclusion of patients with a prior surgical procedure allowed for more accurate evaluation of arthritis progression and conversion to arthroplasty[9,23,29-31]. In addition, the initial MRI of each patient was evaluated by 2 independent reviewers for verification of injury characteristics, instead of evaluating bone scans or radiographs[32-34]. The strict criteria to define root tears as root avulsions or complete tears within 9 mm of attachment allowed a clearer, more reproducible interpretation of the data[16]. As far as study limitations, although we identified risk factors for progression of SIFK to arthroplasty, the retrospective study design precluded strong conclusions because of the presence of confounding and selection bias[35]. In addition, this cohort had a small percentage of patients with long-leg radiographs for assessment of alignment, and the minimum follow-up was 1 year. These factors limited the impact of the results of the study. Nonetheless, well-designed observational studies do not overestimate the magnitude of effects compared with randomized trials[36].

Conclusions

Subchondral insufficiency fractures predominantly involved the medial compartment of the knee and commonly presented with medial meniscal root and radial tears. Approximately one-third of the patients (66 of 223) progressed to total knee arthroplasty. Baseline arthritis, older age, location of SIFK on the medial femoral condyle and medial tibial plateau, meniscal extrusion, and varus malalignment were all associated with progression to arthroplasty. ■

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