Internal Fixation of Unstable Osteochondritis Dissecans of the Knee

Long-term Outcomes in Skeletally Immature and Mature Patients

Martin Husen,[*†] MD, Goran S. Van der Weiden,[‡] MD, Roel J.H. Custers,[‡] MD, PhD, Keshav Poudel,[*] BS, Michael J. Stuart,[*] MD, Aaron J. Krych,[*] MD, and Daniël B.F. Saris,[*§] MD, PhD

Investigation performed at Mayo Clinic, Rochester, Minnesota, USA, and University Medical Center Utrecht, the Netherlands

Background: Osteochondritis dissecans (OCD) is a disorder originating in the subchondral bone, leading to focal lesions with risk of fragmentation and secondary damage of the articular cartilage. It remains controversial if surgical treatment of such lesions is equally successful in skeletally immature and mature patients.

Purpose: To determine (1) the long-term clinical success rate after internal fixation of unstable OCD in skeletally immature and mature patients based on physeal status, (2) if patient-specific and procedural variables influence the risk of failure, and (3) patient-reported outcome measures over time.

Study Design: Cohort study; Level of evidence, 3.

Methods: A multicenter retrospective cohort study was conducted investigating skeletally immature and mature patients treated for unstable OCD lesions of the knee between 2000 and 2015. The healing rate was assessed by radiological imaging and clinical follow-up. Failure was defined as any definitive reoperation for the initially treated OCD lesion.

Results: A total of 81 patients met inclusion criteria, including 25 skeletally immature patients and 56 patients with closed physes at the time of surgery. After a mean follow-up time of 11.3 ± 4 years, 58 (71.6%) patients had healed lesions, whereas the lesions failed to heal in 23 (28.4%) patients. No significant difference in risk of failure was observed based on physeal maturation status (hazard ratio, 0.78; 95% CI, 0.33-1.84; *P* = .56). Lateral versus medial condylar lesion location conferred an increased risk of failure ($P < .05$) for both skeletally immature and mature patients. Multivariate analysis of skeletal maturity status showed that a lateral femoral condylar location was an independent risk factor for failure (hazard ratio, 0.22; 95% CI, 0.1-0.5; $P < .05$). The mean patient-reported outcome scores (International Knee Documentation Committee [IKDC] score and Knee injury and Osteoarthritis Outcome Score [KOOS]) increased significantly after surgery and remained high at the final follow-up ($P < .05$). The final scores (mean ± SD) at a mean follow-up of 135.8 months (range, 80-249 months) were IKDC, 86.6 ± 16.7; KOOS Pain, 88.7 ± 18.1; KOOS Symptoms, 89.3 ± 12.6; KOOS Activities of Daily Living, 89.3 ± 21.6; KOOS Sport and Recreation, 79.8 ± 26.3; and KOOS Quality of Life, 76.7 ± 26.3.

Conclusion: The long-term results after internal fixation of OCD fragments show high rates of healing and sustainable subjective improvement of knee function and quality of life. A healing rate of 72% was noted at a mean follow-up of 11.3 years. The stage of skeletal maturity had no significant influence on the rate of failure. Lateral femoral condylar lesion location is an independent risk factor for failure in skeletally mature and immature patients.

Keywords: osteochondritis dissecans; OCD; cartilage repair; osteochondral repair; skeletal immaturity; knee joint

Osteochondritis dissecans (OCD) is a disorder predominantly found in pediatric and adolescent populations, with an incidence of approximately 0.03% in males and 0.02% in females aged 10 to 20 years.[34,47] A particular predilection for the medial femoral condyle (MFC; 70%-80%) has been reported, followed by the lateral femoral condyle (LFC; 15%-20%) and the patella (5%-10%).[23,29] The disorder is characterized by acquired focal lesions of the subchondral bone, which can progress to fragmentation of the lesion and cause secondary damage to the overlying

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cartilage tissue.[18,54] Although the initiating pathogenesis is not yet fully understood, lesions are histologically characterized by focal osseous necrosis, bony collapse, and subsequent sinking and destabilization of the covering layer of articular cartilage.[18,19,22,54] Causes including vascular disruption, repetitive microtrauma, and hereditary factors have been proposed as lesions can resemble the appearance of an avascular necrosis, often demonstrate scintigraphic enrichment suggesting an increased bone metabolism as found in traumatic fractures, and show familial accumulation, with 14% of patients with OCD having a family history of the disease.[13,21,22,25,54]

The initial stages of the disorder are often characterized by few if any symptoms, impeding early diagnosis and treatment.[44] In later stages, the lesion can transition and become unstable and ultimately progress to a loose body, resulting in painful mechanical symptoms such as catching, locking, or instability.[20] While lesion characteristics such as location, size, and stability guide treatment decisions, nonoperative treatment of stable OCD lesions is usually the first choice in skeletally immature patients, resulting in a healing rate of approximately 50% to 60%.[12,14,16,60] The intrinsic healing response is much lower in skeletally mature patients, leading to a significantly decreased success rate of nonoperative treatment in the adolescent group of 30% to 40%.[11,16,23,46,58] For skeletally immature patients with a stable lesion, a trial of nonweightbearing, unloader braces and the restriction of sports activities are considered treatment options at the initial stage of OCD in patients with potential for healing.[15,23,34,35,38] A variety of surgical techniques are available to address different lesion stages and sizes. Accepted indications for surgical treatment are unstable lesions with visible loose body, detachment of the lesion occurring during observation or nonoperative treatment, juvenile stable lesions remaining symptomatic despite adequate nonoperative treatment, and an established nonunion of a fragment within its bony bed.[13,25,56] A variety of surgical techniques are part of the surgeon's armamentarium, but utilization varies widely among providers for both skeletally immature and mature populations. Sole excision of the detached fragment leads to elevated rates of osteoarthritis and consecutive partial or total knee arthroplasty (TKA) compared with fragment-preserving modalities.[6,39,59,64,66] Surgical techniques such as retrograde or anterograde drilling alone are indicated for low-grade (intact and stable) lesions in skeletally immature patients.[5,49,56] Reduction and internal fixation of the fragment is the most common surgical treatment for unstable OCD fragments among both skeletally immature and adolescent patients with closed physis.[1,11] In the presence of a salvageable unstable fragment with good overlying cartilage and $\geq$3 mm of attached subchondral bone, refixation of the fragments is associated with promising healing rates in the recent literature, ranging from 75% to 100% in skeletally immature patients.[1,41,57,62,69] Reported rates for skeletally mature patients are lower and range from 67% to 86%.[9,33,40,63] The optimal fragment refixation material remains controversial. It has been observed that metal screw fixation was associated with excellent results, while some resorbable materials used in an experimental setting initiated allergic and/or synovial reactions and cartilage damage, which was not seen when using metal screws.[42,65]

No study to date has investigated the influence of physeal status on long-term healing rates after internal fixation of unstable OCD fragments. Therefore, the purpose of our study was to determine (1) the long-term clinical success rate after internal fixation of unstable OCD lesions in skeletally immature and mature patients based on physeal status, (2) if patient-specific and procedural variables influence the risk of failure, and (3) patient-reported outcome measures over time.

METHODS

This retrospective cohort study was performed from 2000 to 2022 at 2 institutions: University Medical Center Utrecht (UMCU) (Utrecht, the Netherlands) and Mayo Clinic (Rochester, Minnesota, USA). Institutional review board (IRB) approval was obtained before the beginning of the study at both locations (UMCU IRB No. 13-kbfu, Mayo IRB No. 15-000601). At UMCU, a single surgeon (D.B.F.S.) performed all procedures. At Mayo Clinic, a search of the institutional medical records database was performed to identify all patients who underwent surgery for OCD of the knee. Patients were included if they underwent internal fixation of an osteochondral fragment using metal and/or bioabsorbable implants. Exclusion criteria consisted of (1) previous internal fixation, osteochondral allograft, osteochondral autograft transfer, or similar procedure in the ipsilateral knee; (2) internal fixation using bone plugs (mosaicplasty); and (3) traumatic osteochondral fracture in the absence of OCD. Of 87 eligible patients, 6 were excluded

[§]Address correspondence to Daniël B.F. Saris, MD, PhD, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, USA (email: saris.daniel@mayo.edu).
*Department of Orthopedic Surgery, Mayo Clinic, Rochester, Minnesota, USA.
[†]Department of Orthopedic Surgery, Heidelberg University Hospital, Heidelberg, Germany.
[‡]Department of Orthopedic Surgery, University Medical Center Utrecht, Utrecht, the Netherlands.
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because of loss to follow-up despite multiple contact attempts by phone, letter, and email.

Internal fixation was indicated for patients with an unstable OCD fragment. Stability was assessed using a combination of clinical, radiographic, and magnetic resonance imaging (MRI) findings and confirmed intraoperatively. The extent of the OCD lesion was graded intraoperatively using the International Cartilage Regeneration & Joint Preservation Society (ICRS) OCD classification (Table 1).[10] Skeletal maturity was assessed using the preoperative radiographs based on the status of growth plate closure (open, partially closed, or closed). Healing was assessed using postoperative MRI when available (31 of 81 patients); otherwise, the last postoperative radiograph was used. The postoperative OCD lesion was classified as follows: healed lesion, complete articular continuity and resolution of underlying bone marrow lesion, and no change, articular incongruity remains with persistence of the bone marrow lesion. Clinical failure was defined as any definitive reoperation for the same OCD lesion, such as refixation, fragment excision, or (osteo-)chondral restoration procedure. Hardware removal was not considered as a failure unless performed for a malfunctioning implant resulting in lesion instability. For patients with healed lesions, pre- and postoperative International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form and Knee injury and Osteoarthritis Outcome Score (KOOS) results were recorded.[67]

Surgical Technique

Diagnostic arthroscopy was typically performed first to assess for size, location, and stability of the lesion. Each surgeon individually determined the need for parapatellar arthrotomy versus arthroscopy, implant type and number, and concomitant procedures. Most cases at one institution were performed with a mini-open technique and metal screws in skeletally mature patients, while fixation with bioabsorbable implants was attempted more frequently for skeletally immature patients at the other site. Stable but ballotable lesions (ICRS OCD grade 2) were fixed in place. Unstable fragments and loose bodies (ICRS OCD grades 3 and 4) were cleaned and reduced into position after curetting the osseous bed to remove fibrous or sclerotic tissue and promote healing. Postoperatively, all patients were placed on a rehabilitation program of touch weightbearing ambulation, full knee range of motion, and hip flexor strengthening for 6 to 8 weeks.

Statistical Analysis

Descriptive statistics including mean, standard deviation, and range were used to characterize results with continuous values, while percentages were used for proportions. Patient and surgery details were compared between groups using Wilcoxon rank-sum tests for continuous variables (age, body mass index [BMI], lesion size, number of implants) and Fisher exact tests for categorical variables (sex, laterality, surgery type, condylar location, lesion stability, implant material). Kaplan-Meier survival curves were constructed for the skeletally immature and mature groups to compare failure rates. A univariate Cox proportional hazards model was used to analyze the risk of failure based on skeletal maturity. Within each group, other risk factors for failure were assessed using odds ratios (ORs) and Fisher exact tests for dichotomous variables along with nominal logistic fit models for continuous or ordinal variables. Significant variables were used to construct a multivariate Cox proportional hazards model for the effect of these variables on failure rate. The patient-reported outcome measures (IKDC and KOOS) were compared using Wilcoxon rank-sum tests; analyses were performed between pre- and postoperative scores for each measure within each group, and for the baseline and final scores between groups.

TABLE 1
International Cartilage Regeneration & Joint Preservation Society Osteochondritis Dissecans Grading System[10]

Grade	Description
1	Stable lesion with a continuous but softened area covered by intact articular cartilage
2	Lesion with partial articular cartilage discontinuity, stable when probed
3	Lesion with complete articular cartilage discontinuity, but no dislocation ("dead in situ")
4	Empty defect, or defect with a dislocated fragment or loose fragment within the bed

Post Hoc Power Analysis

A post hoc power analysis was performed to determine the sample size by use of a 2-sided hypothesis test at an alpha level of .05, a power of 0.8, a sample proportion of 2:1 in the matched cohorts, and hazard ratios (HRs) of 3 and 2. For a survival analysis with an HR of 2, a total of 73 events (failures) would be needed, whereas only 29 events (failures) would be needed for an HR of 3. This study contained a total of 23 events (failures) combined in the skeletally mature and immature groups.

RESULTS

Study Group Characteristics

A total of 81 patients met the inclusion criteria for this study: 26 from UMCU and 55 from Mayo Clinic (Table 2). Six patients were lost to follow-up and therefore were not included in the final study (follow-up rate of 93%). There were 25 skeletally immature patients (12 with open physes, 13 with partially open physes) and 56 skeletally mature patients (closed physes). The mean follow-up time was 11.3 $\pm$ 4 years and 17 patients had undergone previous procedures of the same knee before index surgery (Table 3). At the time of index surgery, 28 concomitant procedures were carried out (Table 4). Of the 81 patients, 58 (71.6%) showed clinical and/or radiographic evidence of

TABLE 2
Patient Characteristics and Procedural Characteristics[a]

Characteristic	Skeletally Immature (n = 25)	Skeletally Mature (n = 56)	*P* Value
Age at surgery, y	15.2 ± 1.9	21 ± 6.1	**<.01**
BMI	23.5 ± 4.8	24.7 ± 4.9	.22
Sex			>.99
Female	6 (24.0)	13 (23.2)	
Male	19 (76.0)	43 (76.8)	
Laterality			.8317
Left	14 (56.0)	34 (60.7)	
Right	11 (44.0)	22 (39.3)	
Surgery type			**.03**
Open	17 (68.0)	49 (87.5)	
Arthroscopic	8 (32.0)	7 (12.5)	
Location[b]			.07[b]
LFC	11 (44.0)	13 (23.2)	
MFC	13 (55.0)	41 (73.2)	
Trochlea	1 (4.0)	2 (3.6)	
Lesion size, cm^3	4.9 ± 1.6	4.2 ± 2.1	.15
ICRS OCD[c]			.09[c]
Grade 2	8 (32.0)	7 (12.5)	
Grade 3	13 (52.0)	29 (51.8)	
Grade 4	4 (16.0)	20 (35.7)	
Fixation material			**<.01**
Bioabsorbable	20 (80)	20 (35.7)	
Metal	5 (20)	36 (64.3)	
No. of fixation devices	3.7 ± 1.4	2.4 ± 1.3	**<.01**

[a]Data are presented as mean ± SD or n (%). Bold *P* values indicate statistical significance. BMI, body mass index; ICRS OCD, International Cartilage Regeneration & Joint Preservation Society Osteochondritis Dissecans classification; LFC, lateral femoral condyle; MFC, medial femoral condyle.

[b]Comparison performed on LFC versus MFC; trochlear lesions excluded because of low sample size.

[c]Comparison performed on proportion of stable (grade 2) versus unstable lesions (grade 3 or 4) in each group.

TABLE 3
Previous Surgeries Performed in Both Groups

Previous Surgery	Skeletally Immature (n = 25)	Skeletally Mature (n = 56)	*P* Value
Drilling	1	5	.66
Partial meniscectomy	2	1	.23
Microfracture	0	2	.99
Loose-body removal	0	2	.99
Debridement	0	1	.99
Other: total meniscectomy, patellar fracture fixation, femoral fracture primary fixation, and revision	0	3	.99

TABLE 4
Concomitant Surgeries Performed in Both Groups[a]

Concomitant Surgery	Skeletally Immature (n = 25)	Skeletally Mature (n = 56)	*P* Value
Bone graft	2	5	.99
Loose-body removal	2	4	.99
Osteochondral allograft transplantation	1	4	.66
Osteotomy	1	2	.99
Drilling	1	1	.99
Other: partial meniscectomy, cyst biopsy, osteochondroma excision, PCL reconstruction, synovectomy, and synovial biopsy	2	3	.37

[a]PCL, posterior cruciate ligament.

TABLE 5
Subsequent Surgeries Performed After Internal Fixation of OCD[a]

Subsequent Surgery	Skeletally Immature (n = 25)	Skeletally Mature (n = 56)	*P* Value
Hardware removal	14	30	.84
Loose-body removal	3	3	.29
Arthrocentesis	3	4	.47
OCD excision	4	5	.35
Osteochondral allograft transplantation	5	2	**<.05**
Autologous chondrocyte implantation	1	4	.59
Total knee arthroplasty	0	1	

[a]Bold *P* value indicates statistical significance. OCD, osteochondritis dissecans.

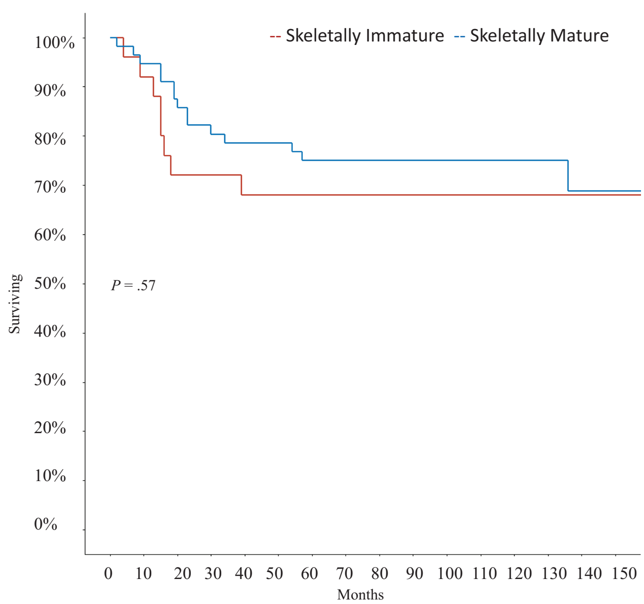

Figure 1. Kaplan-Meier survival analysis curves showing the failure and survival after reduction and internal fixation of osteochondritis dissecans lesions in the knee (*P* = .57). Lower line, skeletally immature; upper line, skeletally mature.

healing at the final follow-up. Failures were recorded in 23 of 81 (28.4%) patients based on the need for further surgical management, including OCD fragment excision, osteochondral allograft transplantation, autologous chondrocyte implantation, repeat fixation, TKA, and synthetic bone graft plug (Table 5). Failure occurred at a mean of 25.7 months (range, 1-136 months) after surgery.

Survival Based on Skeletal Maturity

Kaplan-Meier survival curves were used to compare time-dependent survival of skeletally immature versus mature patients (Figure 1). Failure occurred in 8 of 25 (32%) skeletally immature patients and 15 of 56 (26.8%) skeletally mature patients. For skeletally immature patients alone, survival free from revision was 92% at 1 year after surgery, 72% at 2 years, 68% at 5 years, and 68% at 10 years. Skeletally mature patients had survival rates of 95%, 82%, 75%, and 73% at 1, 2, 5, and 10 years, respectively (*P* = .56) (Figure 1). The combined survival rates were 94%, 79%, 73%, and 72% at 1, 2, 5, and 10 years, respectively. In the univariate Cox proportional hazards model for skeletal maturity alone, there was no significant difference in the risk of failure between the skeletally mature and immature groups (HR, 0.78; 95% CI, 0.33-1.84; *P* = .57).

Intergroup Analysis

Because of the preoperative differences in surgery type (open vs arthroscopic) and implant material used (bioabsorbable vs metal), Kaplan-Meier analysis was conducted to assess survival by these characteristics in the overall group along with intergroup differences in survival within each group (skeletally mature and immature groups).

In the group overall, there was no difference in survival by type of approach (arthroscopic, 77% vs open, 73%; *P* = .75) (Figure 2) or fixation material (metal, 68% vs bioabsorbable, 75%; *P* = .48) (Figure 3). Results were similar in the skeletally immature group where surgery type (arthroscopic, 69% vs open, 62%; *P* = .72) and screw material (metal, 40% vs bioabsorbable, 75%; *P* = .13) were not significant for survival within the group. In the skeletally mature group, surgery type (arthroscopic, 71% vs open, 73%; *P* = .83) and screw material (metal, 72% vs bioabsorbable, 75%; *P* = .65) were also not significantly different for survival within the group.

Risk Factor Analysis

Risk factors for failure were first analyzed independently within the skeletally immature and mature groups (Table 6). In the skeletally immature group, LFC lesions conferred a 37-fold increase in the odds of failure over medial lesions (OR, 36.8; 95% CI, 1.87-1465.6; *P* < .05); therefore, a multivariate Cox proportional hazards model was used to evaluate the interaction between skeletal maturity and lesion location. The multivariate analysis of skeletal maturity status showed that a lateral femoral condylar location was an independent risk factor for failure (hazard ratio, 0.22; 95% CI, 0.1-0.5; *P* < .05). Skeletal immaturity did not significantly affect the failure rate (HR, 0.84; 95% CI, 0.18-2.41; *P* = .76), and lesions on the LFC conferred no elevated HR in the skeletally immature (HR, 0.08; 95% CI,

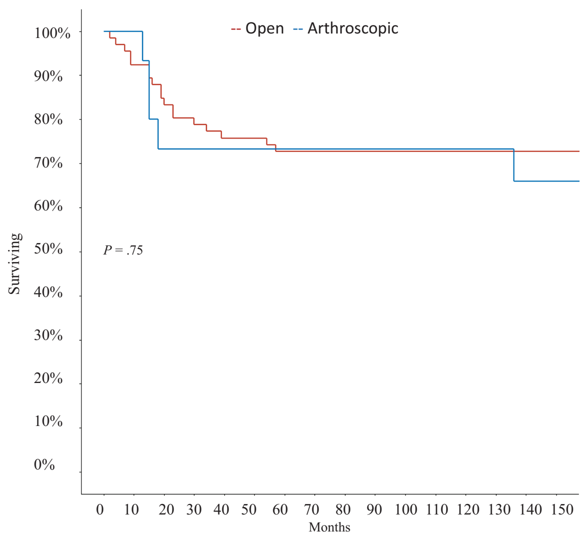

Figure 2. Kaplan-Meier survival curves in the overall group by approach (open vs arthroscopic).

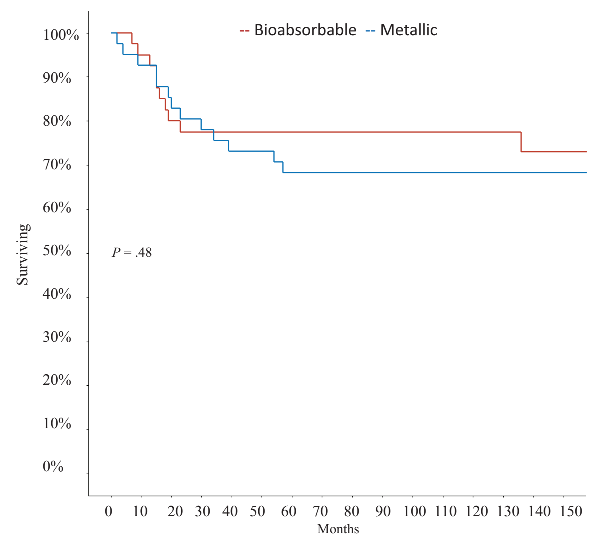

Figure 3. Kaplan-Meier survival curves in the overall group by fixation material (metallic vs bioabsorbable).

TABLE 6
Univariate Analysis of the Hazard Ratio of Failure Based on Different Variables in the Skeletally Immature and Mature Groups[a]

	Skeletally Immature[b]		Skeletally Mature[c]	
Variable	HR (95% CI)	*P* Value	HR (95% CI)	*P* Value
Sex: female vs male	2.57 (0.32-20.96)	.38	1.37 (0.39-4.86)	.62
Laterality: left vs right	1.34 (0.33-5.35)	.68	2.07 (0.75-5.70)	.16
Surgery type: open vs arthroscopic	1.3 (0.31-5.5)	.72	0.85 (0.18-3.94)	.83
Location: LFC vs MFC	0.1 (0.01-0.65)	**<.05**	0.37 (0.13-1.09)	.07
ICRS OCD: stable (grade 2) vs unstable (3 or 4)	1.11 (0.41-3.01)	.61	1.14 (0.54-2.43)	.74
Implant material: bioabsorbable vs metal	2.93 (0.7-12.27)	.14	1.29 (0.42-3.91)	.66
No. of implants	1.28 (0.8-2.07)	.31	1.02 (0.7-1.49)	.91

[a]Bold *P* value indicates statistical significance. HR, hazard ratio; ICRS OCD, International Cartilage Regeneration & Joint Preservation Society Osteochondritis Dissecans classification; LFC, lateral femoral condyle; MFC, medial femoral condyle.
[b]8 (32%) failures.
[c]15 (26.8%) failures.

0.01-0.65; $P < .05$) and mature (HR, 0.37; 95% CI, 0.12-0.9; $P = .07$) cohorts (Figure 4). Otherwise, there was no significant change in the risk ratio of failure in either group based on sex, laterality, type of surgery (open/arthroscopic), implant material, lesion stability, or condylar location in the skeletally mature group alone (Table 6). The continuous and ordinal variables were analyzed separately using nominal logistic fit models. There were no significant differences in failure rate based on BMI (immature, $P = .65$; mature; $P = .45$), lesion size (immature, $P = .32$; mature, $P = .68$), ICRS grade (immature, $P = .43$; mature, $P = .09$), or number of implants (immature, $P = .23$; mature, $P = .20$). Kaplan-Meier survival curves for skeletally mature and immature patients were also constructed by lesion location as noted in Figure 5. In both the skeletally immature ($P < .05$) and the mature ($P < .05$) groups, LFC lesions showed significantly worse survivorship when compared with MFC lesions (Figure 6).

Patient-Reported Outcome Measures

Outcomes were assessed using the IKDC score and KOOS (Figure 7). The scores were reported at a mean follow-up of 135.8 months (range, 80-249 months) after surgery. Outcome scores were compared between the skeletally immature and mature groups before surgery ($P > .05$) and at a minimum of 6 years after surgery ($P > .05$). Mean scores were significantly increased on final assessment when compared with preoperative scores ($P < .01$). Overall, the mean final IKDC score was 86.6 ± 16.7 and the mean final KOOS values were 88.7 ± 18.1 for Pain, 89.3 ± 12.6 for Symptoms, 89.3 ± 21.6 for Activities of Daily Living (ADL), 79.8 ± 26.3 for

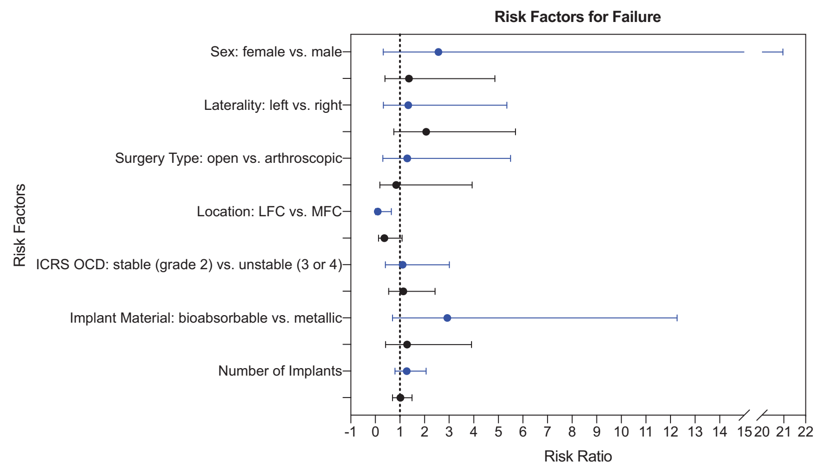

Figure 4. Forest plot of risk factors for failure and conferred risk ratio. For each risk factor: top lines, skeletally immature; bottom lines, skeletally mature. ICRS OCD, International Cartilage Regeneration & Joint Preservation Society Osteochondritis Dissecans classification; LFC, lateral femoral condyle; MFC, medial femoral condyle.

Sport and Recreation, 76.7 ± 26.3 for Quality of Life (QOL). There was no significant difference in failure rates between the cohorts, the same applied for the IKDC score, which was higher in the skeletally immature group (*P* = .09). The KOOS values between both cohorts remained high at the final follow-up, with combined scores as follows: 88.7 ± 18.1 for KOOS Pain, 89.3 ± 12.6 for KOOS symptoms, 89.3 ± 21.6 for KOOS ADL, 79.8 ± 26.3 for KOOS Sport and Recreation, and 76.7 ± 26.3 for KOOS QOL. While most KOOS values were consistent among cohorts, the KOOS Sport and Recreation value was lower in the mature cohort (74.8 ± 29.1) than in the immature group (83.9 ± 24.4) (*P* <.05).

DISCUSSION

This comparative cohort study of 81 patients at a mean follow-up of 135.8 months after surgery provides the longest follow-up of OCD fixation in the literature to date.

The primary finding of this study is the stable success rate after fixation of knee OCD lesions within our cohort. In 2018, Wu et al[67] reported a healing rate of 76% at a mean follow-up of 60 months. Within our cohort, the success rate remained high at 71.6% after more than twice the follow-up time. This suggests that failure occurs relatively early after initial therapy, and results remained stable after 5 years. Similar results were reported by Anderson et al,[5] who reported on 40 skeletally mature patients treated for OCD lesion fixation and followed up for 5 to 7 years, with no failure reported after 5 years. Further, univariate and multivariate analyses showed no significant differences in the risk of failure based on skeletal maturity. However, the success rate of therapy was significantly influenced by lesion location, with a higher treatment success seen in lesions of the MFC, while lesions of the LFC were associated with a significantly higher failure rate in both groups. Overall, both groups demonstrated good healing rates and high patient-reported outcomes that were significantly improved after index surgery and remained at a stable level at final follow-up, suggesting that internal fixation of osteochondral fragments is a viable treatment option with lasting long-term results in a pediatric and adolescent patient cohort, regardless of physeal status.

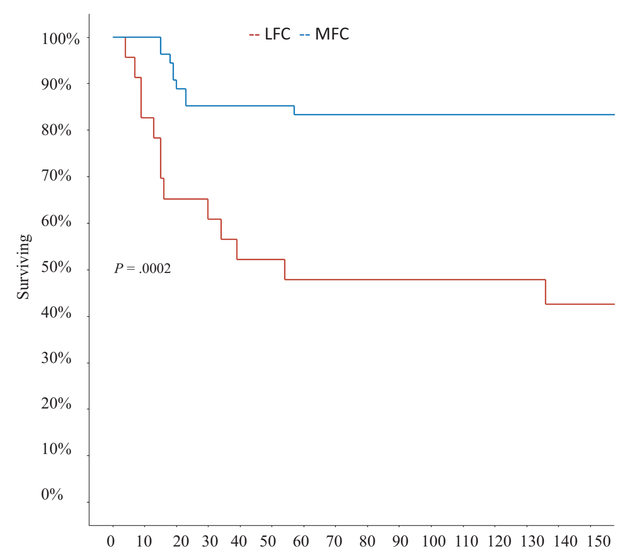

Figure 5. Kaplan-Meier survival curves in the overall group by lesion location: medial femoral condyle (MFC) versus lateral femoral condyle (LFC).

We report a clinical success rate of 68% in the skeletally immature cohort and 73.2% among skeletally mature patients. No statistical differences were found between the 2 groups. Common dogma dictates that the treatment success rate is anticipated to be higher in skeletally immature patients, facilitated by a stronger intrinsic healing response after reduction and fixation.[23,24,27,31,52,62] This hypothesis is not supported by our current study. Previous studies reported healing rates for skeletally immature patients ranging from 70% to 100% after internal fixation

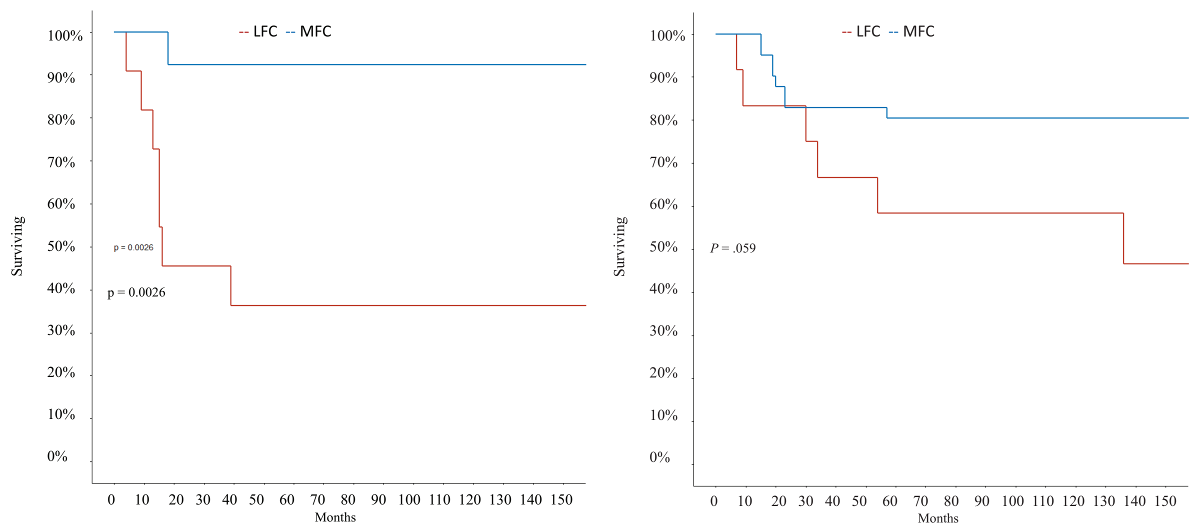

Figure 6. Subgroup analysis of lesion location. Kaplan-Meier survival curve of the skeletally immature group (left) and mature group (right) discriminated by lateral (LFC) and medial (MFC) femoral condyles.

with bioabsorbable and/or metal implants.[45,55,61,67,68] Rates in skeletally mature patients were found to be between 30% and 86%.[9,24,32,33,40,48] Because of the relative rarity of OCD, many studies combine patients of both cohorts, irrespective of the physeal status, resulting in healing rates similar to those generally found in skeletally immature patients.[2,17,30,36,43] The time of follow-up and patient numbers of the aforementioned case series are limited, resulting in susceptibility for patient selection bias, small sample sizes, and restricted significance for long-term results. To address these limitations, we utilized larger patient cohorts, matched comparisons, long-term follow-up, and multivariate and subgroup analysis to contribute novel and more robust data to the scientific fundament of the continued academic debate.[68]

It has been reported that patients with OCD undergo TKA at a younger age than the primary TKA population.[47] The rate of conversion to TKA seen at a mean of 11.3 years of follow-up in this study is reassuring, with only 1 patient from the overall cohort converted to TKA at age 52. This rate falls below previous estimates for skeletally immature and mixed maturity populations treated for OCD of the knee, with previously available studies trending toward higher TKA conversion rates.[3,4,53] However, long-term data are very limited in the existing literature, with the longest currently available mean follow-up reporting on OCD treatment of 22 knees being 33.6 years.[59] This study was published in 1991 and reported on patients treated between 1953 and 1971. Similarly, a large number of further publications in the field of OCD are of advanced age, displaying the medical history and advancement of surgical techniques, but inherently falling short of contributing up-to-date data as treatment guidance for physicians and patients.[4] Continued surveillance of our reported multicenter group will further outline long-term results of internally fixated OCD lesions in the knees of immature and mature patients, resulting in further understanding of the benefits and limitations of modern surgical techniques.

We carried out a risk factor analysis for failure according to skeletal maturity. Sex, BMI, laterality, surgery type (open vs arthroscopic), lesion size, ICRS grade, number of implants, and implant material (bioabsorbable vs metal) had no statistically significant effect on clinical failure rate. Both groups showed a dependency on lesion location, with an increased failure risk for LFCs in the skeletally immature cohort ($P < .01$) and in the skeletally mature cohort ($P = .05$). A location dependency was also described by Hefti et al,[23] who found an elevated healing rate for unstable lesions located on the MFC near the fossa compared with lateral lesions. This was also supported by Webb et al,[62] who analyzed healing rates for internal fixation of unstable OCD lesions in skeletally immature patients, finding that all 5 failures occurred in the 11 knees with LFC lesions. In addition, Paletta et al[46] investigated unstable, unsalvageable OCD lesions treated with mosaicplasty and found a correlation of LFC location and poorer clinical outcomes. In contrast, Kocher et al[28] reported no location-dependent difference in healing rate in a skeletally immature cohort. Furthermore, Cahill et al[14] found lower healing rates for MFC lesions in nonoperatively treated patients but did not distinguish by physeal status. Similar findings were reported by Wall et al,[60] who analyzed nonoperative treatment of stable juvenile OCD lesions and found better healing rates for the LFC lesion location. However, when comparing the results of the current study with the available literature, it is important to note that previous studies typically reported on much smaller cohorts and/or followed up for a fraction of the time of the current study. Therefore, failure rates are not always comparable. In summary, there seems to be an association of unstable OCD lesions located at the LFC and an elevated failure rate, while stable OCD lesions show no

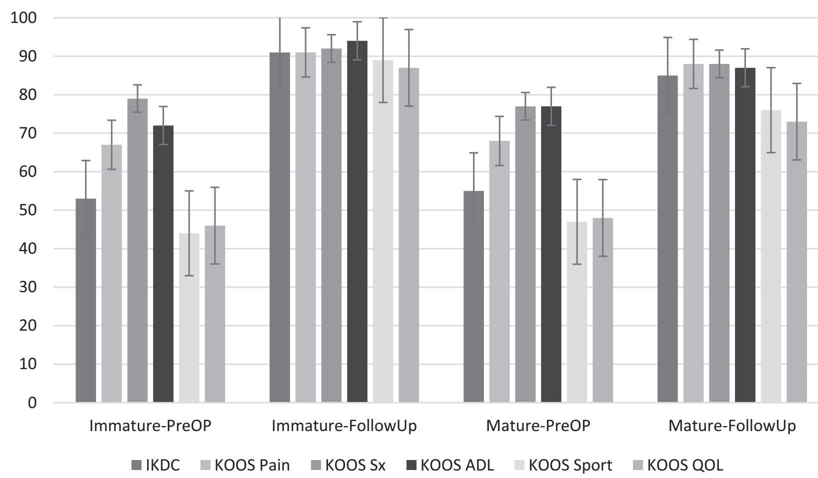

Figure 7. Comparison of International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form and Knee injury and Osteoarthritis Outcome Score (KOOS) results. Error bars indicate SE. ADL, Activities of Daily Living; PreOP, preoperative; QOL, Quality of Life; sport, Sport and Recreation; Sx, other symptoms.

location-dependent difference in healing and are associated with slightly better outcomes when located at the LFC. A possible reason for this correlation might lie in the larger size of the LFC anteroposteriorly and the lesions being predominantly located within the biomechanical main stress zone.[62] Lesions that remain stable may be subject to less biomechanical force, facilitating a better healing environment and enabling nonoperative treatment, while the much rarer LFC lesions are mainly found in the posterior center of the condyle.[11]

Patient-reported outcomes in both groups were significantly improved after index surgery. Further, scores remained at the same level at the time of final follow-up without a significant drop in function and patient satisfaction. The mean IKDC score at a mean follow-up of 11.3 years was 86.6 ± 16.7 for both groups combined. In the subgroup analysis, the skeletally immature cohort reported an IKDC score of 91.2 ± 10.9 and the skeletally mature cohort had an IKDC score of 84.5 ± 18.5. While the score of the skeletally immature group was exceptionally high compared with previous studies, the skeletally mature cohort's score was mostly consistent with the available literature (range, 53-85).[9,27,37,40,51,62] As there was no significant difference in failure rates between the cohorts, the same applied for the IKDC score, which was higher in the skeletally immature group (P = .09), mirroring the findings by Pascual-Garrido et al,[50] who also reported better IKDC scores at final follow-up for their skeletally immature cohort. The KOOS values between both cohorts remained high at the final follow-up, with a combined scores as follows: 88.7 ± 18.1 for KOOS Pain, 89.3 ± 12.6 for KOOS symptoms, 89.3 ± 21.6 for KOOS ADL, 79.8 ± 26.3 for KOOS Sport and Recreation, and 76.7 ± 26.3 for KOOS QOL. While most KOOS values were consistent among cohorts, the KOOS Sport and Recreation value was lower in the mature cohort (74.8 ± 29.1) than in the immature group (83.9 ± 24.4) ($P < .05$). Barrett et al[9] previously reported on 22 skeletally mature patients with a mean follow-up of 8.7 years and found slightly higher scores after internal fixation (Pain, 93; Symptoms, 86; ADL, 98; Sport and Recreation, 82; QOL, 76). They found fragment union to be an important prognostic factor and stated that healed lesions led to superior outcomes compared with lesions that failed to heal.[9] The results published by Magnussen et al[36] on a mixed maturity cohort of 12 patients were in the same realm as in the current study, although after a shorter mean follow-up of 9.5 years. Similarly, Gomoll et al[20] reported a KOOS ADL of 96.8 ± 3.7 and a KOOS QOL of 79.7 ± 17.1 after internal fixation of unstable Cahill 2b lesions and a 6-year follow-up.

There are some limitations in our study design. (1) The first line of follow-up was a telephone interview. If a patient could not be reached via telephone despite ≥3 attempts on different weekdays and at different times of day, then email questionnaires were sent out. If these emails remained unanswered, letter-based questionnaires were mailed. Our use of a mailed questionnaire to obtain long-term follow-up exposes the study to certain biases. As was demonstrated by Kim et al,[26] patients with poorer outcomes are less likely to return questionnaires and tend to take longer to return them when they do so. We attempted to minimize this possible bias by being persistent in our data gathering, reaching a follow-up of 93%, but our failure to obtain 100% follow-up must be considered when interpreting data from our cohort of patients. (2) Our long-term results consist only of patient-reported outcomes and a determination of whether the patient required subsequent surgery on the index knee. We believe that given the size and bony nature of the OCD lesions, they would be symptomatic and require excision or repeat fixation if they were to again become unstable fragments. This supposition is supported by the fact that patients initially encountered relevant symptoms from these unstable fragments, ultimately leading to the index surgery. (3) We describe a single method of treatment for both patient groups without comparison with another treatment approach. This is because of the evidence that internal fixation of unstable OCD lesions is superior to other treatment modalities, and salvage of autologous tissue is associated with better clinical outcomes than allograft transplantation, lesion excision, or cell-based treatments, especially in a pediatric and adolescent patient cohort.[8] Supporting this assumption, previous authors have demonstrated poor outcomes or evidence of osteoarthritis in 50% to 75% of patients at 5- to 15-year follow-ups using alternative surgical techniques.[4,7,23,70]

CONCLUSION

Internal fixation of unstable OCD lesions is a viable surgical treatment leading to long-term stable results in both skeletally immature and mature patients. Lasting functional and subjective improvement was demonstrated in the current cohort. Complications resulting in need for reoperation are infrequent and typically occur in the first 5 years after index surgery, after which the results remain stable. LFC lesions are at higher risk of failure compared with MFC lesions. Internal fixation of unstable OCD lesions should be attempted, when possible, to restore articular congruence and preserve native hyaline cartilage.

ORCID iDs

Martin Husen https://orcid.org/0000-0002-2852-9542
Aaron J. Krych https://orcid.org/0000-0003-3248-8007

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