Return to Athletic Activity After Osteochondral Allograft Transplantation in the Knee

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Background: Fresh-stored osteochondral allografts have been used successfully to resurface large chondral and osteochondral defects of the knee. However, there are limited data available for the return to athletic activity.

Purpose: To review the rate of return to athletic activity after osteochondral allograft transplantation in the knee and to identify any potential risk factors for not returning to sport.

Study Design: Case series; Level of evidence, 4.

Methods: Forty-three athletes were treated with fresh-stored osteochondral allograft transplantation for symptomatic large chondral or osteochondral defects of the knee from 2000 to 2010. The average age of the athletes (30 men, 13 women) was 32.9 years (range, 18-49 years). Patients were prospectively evaluated by International Knee Documentation Committee (IKDC), activities of daily living scale of the Knee Injury and Osteoarthritis Outcome Score (KOOS), Marx Activity Rating Scale, and Cincinnati Sports Activity Scale scores. A multivariable regression analysis was performed to identify potential risk factors for failure to return to sport at the preinjury level.

Results: At an average 2.5-year follow-up, limited return to sport was possible in 38 of 43 athletes (88%), with full return to the preinjury level achieved in 34 of 43 athletes (79%). In these 34 athletes, time to return to sport was 9.6 $\pm$ 3.0 months. Age $\geq$25 years (P = .04) and preoperative duration of symptoms greater than 12 months (odds ratio, 37; P = .003) negatively affected the ability to return to sport. In the athletes who returned to their previous level of competition, IKDC ($P < .001$), KOOS (P = .02), and Marx Activity Rating Scale ($P < .001$) scores were all significantly greater than in those athletes who did not return to sport.

Conclusion: Osteochondral allograft transplantation in an athletic population for chondral and osteochondral defects in the knee allows for a high rate of return to sport. Risk factors for not returning to sport included age $\geq$25 years and preoperative duration of symptoms $\geq$12 months.

Keywords: osteochondral allograft; athletics; knee; articular cartilage defect

Chondral and osteochondral defects of the knee are a relatively common but challenging clinical entity. In particular, osteochondral lesions that are larger than 2.5 cm^2 may be difficult to treat using commonly applied marrow stimulation techniques[2,7,8,18] or autologous chondrocyte implantation (ACI), as these methods do not restore normal bony condylar architecture.[11,35] The implantation of fresh osteochondral allografts provides a potential solution because it provides immediate structural integrity to the joint surface by transplanting structural bone and viable hyaline articular cartilage into the defect. Several studies confirm the effectiveness of osteochondral allografts in reliably providing pain relief and return of function for activities of daily living.[12,17,33,49] However, most studies reporting the clinical results of osteochondral allograft transplantation have used clinical assessment tools that were designed for less active patients.[12,17]

Articular cartilage injuries in athletes have been described with increasing frequency.[9,34,36] Data for the return to activity in this population are currently reported for treatment with ACI,[29,39,40] microfracture,[41,48] and osteochondral autologous transfer.[18,19] Two recent systematic reviews of these 3 cartilage repair techniques by

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Mithoefer et al[37] and Harris et al[24] showed continued sports participation at the preinjury level in 65% and 66% of athletes, respectively. However, notably absent from the current literature are any data concerning osteochondral allograft transplantation in athletes.

Therefore, the purpose of this study was to retrospectively review prospectively collected functional outcomes and return to athletic participation in 43 patients with isolated chondral and osteochondral defects of the knee that were treated with osteochondral allograft transplantation. Our aim was to determine (1) the rate of return to full sports participation as defined by attaining the preinjury level of the Cincinnati Sports Activity Scale (CSAS); (2) validated functional outcome measures including International Knee Documentation Committee (IKDC), Knee Injury and Osteoarthritis Outcome Score (KOOS), and Marx Activity Rating Scale scores in an athletic cohort; and (3) risk factors for not returning to sport in this challenging athletic population. Based on our clinical observations, we hypothesize that osteochondral allograft transplantation will result in a high rate of return to sport.

MATERIALS AND METHODS

In 1999, our institution adopted a prospective registry to monitor the outcomes of patients after cartilage repair procedures. The Institutional Review Board approved the registry, and all patients signed an informed consent form before participation. Patients included in the registry were evaluated preoperatively and were prospectively followed at 6 months and 1, 2, 3, 4, 5, and 10 years postoperatively.

For this study, we included patients who regularly participated in sports before articular cartilage injury with isolated chondral and osteochondral lesions of the knee treated with fresh-stored osteochondral allograft transplantation from 2000 to 2010 with a minimum 1-year follow-up. Athletic participation before injury was at the recreational (74%), collegiate (23%), and professional (2%) levels. Patients aged younger than 18 years or older than 50 years at the time of surgery, patients who underwent concomitant meniscal transplant, and patients with misalignment necessitating realignment osteotomy were excluded (defined as deviation from the mechanical axis on long leg standing films greater than 5°). Patients with either previous or concomitant anterior cruciate ligament reconstructions were not excluded, as a significant number of cartilage injuries result from this injury in an athletic population.[46] In addition, patients were not excluded for having had prior cartilage procedures. All patients participated in athletics before the onset of knee-based symptoms and desired postoperative participation. All patients had magnetic resonance imaging (MRI) examinations at the time of evaluation to measure the size of the lesion in the sagittal and coronal planes. Patients were indicated for osteochondral allografts for symptomatic focal chondral and osteochondral lesions of the knee greater than 2.5 cm^2 and without generalized osteoarthritis.

Seventy percent of the athletes were men, and 30% were women. The mean age was 33 ± 10 years (range, 18-49 years). The mean body mass index (BMI) was 27.9 ± 4.1 (range, 21-38). The patients had undergone a mean of 1.1 ± 1.4 surgical procedures before osteochondral allograft transplantation (range, 0-6 procedures). Fifty-eight percent of the patients had prior surgery to the affected knee. Ten patients (23%) had failed previous cartilage procedures, including 7 microfractures, 1 autologous osteochondral graft, 1 ACI, and 1 synthetic biphasic scaffold. Preoperative duration of symptoms averaged 14.8 ± 18.1 months (range, 5-120 months). Lesion size averaged 725 ± 236 mm^2 (range, 250-1394 mm^2). Lesions were located on the medial femoral condyle (40%), lateral femoral condyle (40%), trochlea (2%), and multiple locations (18%). The mean number of transplanted plugs was 1.9 ± 0.9 (range, 1-4). Fifty-one percent reported a traumatic cause of the cartilage defect, 37% a nontraumatic cause, and 12% osteochondritis dissecans defects.

All procedures were performed by fellowship-trained, board-certified orthopaedic surgeons who were experienced with the technique. Patients were treated with an initial diagnostic arthroscopy of the joint for assessment of the osteochondral lesion as well as the other articular surfaces, menisci, and ligaments. Osteochondral allograft transplantation was performed via the technique described by Williams et al.[49] Lesions were exposed via a small parapatellar arthrotomy and debrided to a stable rim. Lesions were then sized and reamed to a bed of normal bone, and an appropriate graft was taken from the corresponding region of the allograft. Lesion depth was also carefully measured at 4 points around the lesion, marked, and matched on the donor tissue. Grafts were gently impacted into place for a press-fit technique. Grafts were a single or dual circular dowel shape in most cases, depending on lesion shape (circular or oblong).

Fresh-stored allografts were obtained from commercially available sources. Sizing was determined preoperatively via measurement of marked radiographs to match the radius of curvature and size. In all cases, donor tissue was screened for pathogens according to the American Association of Tissue Banks guidelines.[6] Grafts were transplanted between 7 and 30 days after harvest based on pathogen screening and patient availability.

Postoperatively, patients remained touchdown or non-weightbearing for a minimum of 4 to 6 weeks, and continuous passive motion was also used. A supervised physical therapy program was undertaken postoperatively in all cases. Duration was dependent on the restoration of normal gait, return of quadriceps function, and performance of sport-specific skills. Return to higher level activities and athletics was initiated on an individual patient basis and was typically predicated on a return of lower extremity strength.

Return to sport and functional outcome were evaluated at a minimum of 1 year after osteochondral allograft transplantation, with a mean follow-up time of 2.5 years (range, 1-11 years). Prospective follow-up evaluation was performed preoperatively and at 6, 12, 24, 36, 48, 60, and 120 months postoperatively. We assessed activity level for each patient using the Marx activity scale for disorders of the knee.[32] In addition, patients self-reported CSAS scores including level of sports activity: level I, participates 4 to 7 days/week; level II, participates 1 to 3 days/week;

level III, participates 1 to 3 times/month; and level IV, no sports.[3] Patients also self-reported the type of activity categorized as the following: jumping/hard pivoting/cutting such as basketball, football, and soccer; running/twisting/turning such as tennis, racquetball, ice hockey, and skiing; no running/twisting/jumping such as cycling or swimming; and no sports.[3] Return to full sport was defined in this study as preinjury CSAS level. The advantages of the CSAS are that it combines both frequency of athletic participation and categorizes activity based on mechanical loads placed on the knee.[3] Limited or partial return to sport was defined as returning to the same type of activity in the CSAS but either at a lower Marx activity scale score or at a lower level (frequency) of participation in that sport.

For functional outcome, we assessed each patient using the IKDC Subjective Knee Form and the activities of daily living scale of the KOOS. The IKDC score is a reliable and valid knee-specific measure of symptoms and function.[25] Although originally designed for the assessment of ligament disruption, the IKDC has been shown to provide a good overall measure of disability in patients who have undergone cartilage regeneration procedures.[20] The activities of daily living scale of the KOOS has shown high reliability, validity, and responsiveness.[31] These knee-specific outcome instruments have been previously validated and used for prospective evaluation of knee articular cartilage repair.[15,28,31,45,47,48]

Descriptive analyses of the patient data were performed using means and standard deviations for continuous variables and frequencies and percentages for discrete variables. After the initial analysis, comparisons of patient characteristics between those who returned to full athletic activity and those who did not were conducted using independent-samples t tests for continuous variables. For categorical variables, independent associations were evaluated using the χ^2 or Fisher exact test. Changes in subjective patient outcome scores (activities of daily living, IKDC, and Marx activity level scale) were assessed using paired t tests comparing various time points to baseline for each procedure group. To adjust for multiple comparisons, the Bonferroni technique was used to adjust the critical P value and minimize the possibility of increased type I error. In addition, a multivariable logistic regression, adjusting for age, sex, and BMI, was performed to assess potential risk factors for not returning to full athletic participation. Two-tailed tests were used for all statistical analyses with a critical α set to .05. All analyses were done using SPSS version 18.0 (SPSS Inc, Chicago, Illinois).

RESULTS

There were no intraoperative complications or graft failures in this group over the period of follow-up. One patient required a manipulation under anesthesia for arthrofibrosis at 6 weeks after surgery. Overall, activities of daily living scores ($P < .01$), IKDC scores ($P < .01$), and Marx Activity Rating Scale ($P = .01$) results were significantly improved from baseline to the time of last follow-up (Table 1).

At an average 2.5-year follow-up, the return to sport rate was 88% (38 of 43 athletes), but return to the previous level of sport was achieved in 34 of 43 athletes (79%). In these 34 athletes, time to return to sport was 9.6 ± 3.0 months (range, 7-13 months). Preoperatively, 18 athletes reported CSAS level I activity (42%), 16 reported level II activity (37%), and 9 reported level III activity (23%). Of the 9 athletes who did not achieve full athletic activity postoperatively, 6 were level III, 2 were level II, and 1 was level I. Preoperatively, 27 patients reported CSAS activity as jumping/hard pivoting/cutting, 7 patients reported activity as running/twisting/turning, and 9 patients reported activity as cycling or swimming (no running/twisting/jumping). Of the 9 athletes who did not achieve full athletic activity postoperatively, 1 was categorized as jumping/hard pivoting/cutting, 4 were running/twisting/turning, and 4 were categorized as cycling or swimming (no running/twisting/jumping).

TABLE 1
Overall Knee Function[a]

Outcome Measure	Baseline	Final	*P* Value
Activities of daily living score	62.00 ± 15.96	82.82 ± 14.18	<.01
IKDC score	46.27 ± 14.86	79.29 ± 15.53	<.01
Marx Activity Rating Scale	5.49 ± 6.35	8.35 ± 5.98	.01

[a]Values shown as mean ± standard deviation. IKDC, International Knee Documentation Committee.

Statistically significant risk factors for not returning to sport included athlete age ≥25 years ($P = .04$). In a multivariate regression model adjusting for athlete age, gender, and BMI, preoperative duration of symptoms greater than 12 months also affected the ability to return to sport ($P = .003$; odds ratio, 37.04; 95% confidence interval, 3.4-398.4) (Table 2).

In the athletes who returned to their previous level of competition, IKDC ($P < .001$), activities of daily living ($P = .02$), and Marx Activity Rating Scale scores ($P < .001$) were all significantly greater than in those athletes who did not return to sport (Table 3).

DISCUSSION

Athletes with cartilage injuries present a treatment challenge, as articular cartilage repair in this population requires a durable cartilage surface restoration that can withstand high mechanical demands. Currently, data for the return to activity are reported for treatment with ACI,[29,39,40] microfracture,[41,48] and osteochondral autologous transfer.[18,19] However, there is a lack of outcome data in athletes after osteochondral allograft transplantation. In this retrospective review of prospectively collected data, the hypothesis that athletes treated with osteochondral allograft transplantation will return to athletic activity at a high rate was confirmed. Patients who were younger than 25 years old and had less than 12 months of preoperative symptoms were more likely to return to full athletic activity.

TABLE 2
Comparison of Demographics, Lesion Characteristics, and Outcome Scores Between Athletes Who Returned to Full Athletic Activity and Those Who Did Not[a]

	No Return to Full Sport Mean ± SD or n (%)	Return to Full Sport Mean ± SD or n (%)	*P* Value
Total N	9 (20.9)	34 (79.1)	
Demographics			
Female gender	4 (44.4)	9 (26.5)	.417
Age, y	35.93 ± 6.53	32.21 ± 10.96	.210
Age ≥25 y	9 (100)	22 (64.7)	.044[c]
Body mass index	28.81 ± 4.96	27.7 ± 3.95	.481
Previous surgery	5 (55.6)	20 (58.8)	>.999
Previous cartilage surgery	3 (33.3)	7 (20.6)	.413
Symptom duration, mo	19.44 ± 10.03	13.59 ± 19.65	.395
Duration ≥12 mo	8 (88.9)	7 (20.6)	<.001[c]
Lesion characteristics			
Lesion area	812.33 ± 174.98	702.17 ± 246.31	.216
Multiple locations	4 (44.4)	5 (14.7)	.073
Multiple plugs	8 (88.9)	19 (55.9)	.121
Sports activity			
Level I[b]	1 (11.1)	17 (50.0)	.057
Competitive athlete (college/professional)	0 (0)	11 (32.4)	.084
Outcome score at most recent follow-up			
Activities of daily living score	67.18 ± 21.3	86.96 ± 7.84	.024[c]
IKDC score	58.79 ± 19.49	84.24 ± 9.47	<.001[c]
Marx Activity Rating Scale	0.78 ± 1.09	10.35 ± 5.04	<.001[c]

[a]SD, standard deviation; IKDC, International Knee Documentation Committee.
[b]Level I: sports history (4-7 d/wk).
[c]Statistically significant ($P < .05$).

TABLE 3
Multiple Logistic Regression Model for Risk Factors for Not Returning to Prior Level of Sport

			95% Confidence Interval	
	P Value	Odds Ratio	Lower	Upper
Duration of symptoms ≥12 mo	.013	42.173	2.233	796.391
Active sports history (4-7 d/wk)	.061	0.093	0.008	1.116
Multiple locations	.653	1.850	0.126	27.078
Multiple plugs	.647	2.561	0.046	142.796
Any previous surgery	.560	0.389	0.016	9.250
Previous cartilage procedure	.889	0.820	0.050	13.326
Concomitant surgery	.433	0.322	0.019	5.468
Lesion area	.850	1.001	0.995	1.006

Several previous series have examined functional outcomes in patients after fresh osteochondral allograft transplant procedures in the knee. Emmerson et al[12] reported a series of 64 patients with a mean age of 28.6 years, mean follow-up of 7.7 years, and mean graft size of 7.5 cm^2 who had undergone fresh osteochondral allograft transplantation for osteochondritis dissecans in the knee. Knee function was assessed by a modified d'Aubigne and Postel score, in which a maximum score for function is given for unlimited walking without a limp, as well as a simple assessment of overall knee function from 1 to 10. Although patients were highly satisfied and showed significant gains by these scales, it is unclear whether higher level activity was achieved in this group of young patients. Williams et al[50] reported a series of 19 patients with fresh osteochondral allografts with clinical and radiographic outcomes at 48 months. Again, function was improved by the activities of daily living scale and SF-36. In addition, these scores correlated with bony incorporation on MRI, but high demand activity was not assessed. McCulloch et al,[33] in their series of 25 patients with fresh osteochondral allografts, provide the most comprehensive functional outcomes with reporting of the Lysholm score, IKDC score, and KOOS. However, the majority of patients in this study had concomitant procedures, primarily meniscal allograft (n = 10) and high tibial osteotomy (n = 4), limiting the analysis of the osteochondral allograft transplant as an isolated procedure.

In this study, we found that 88% of athletes returned to partial activity and 79% returned to full athletic activity. This compares favorably with other cartilage repair techniques currently reported in the literature for an athletic population. Mithoefer et al[37] recently performed a systematic review of microfracture, autologous mosaicplasty, and ACI in athletes and found a return to a preinjury level of 65%. They found that the highest rates of return were in patients treated with osteochondral autografts but that the most durable results were in athletes treated with ACI.[37] The main confounding variable is that most ACI patients also underwent osteotomy, which may have contributed to the longevity of the cartilage repair. Harris and colleagues[24] performed a similar systematic review and found a return to the preinjury level of 66%. They found lower rates of return to sport after microfracture than compared with either ACI or autologous osteochondral transfer. Regarding data for specific cartilage repair techniques, Steadman et al[48] described a return rate of 76% in professional football players after microfracture. In contrast, other studies report 44% to 58% of athletes have been able to return to athletic activity after undergoing microfracture.[16,38,41] For osteochondral autografts, Kish and colleagues[27] described a mixed population of athletes and nonathletes with a return to full activity in 61% of patients at an average follow-up of 26 months. A randomized, prospective study of microfracture versus autologous mosaicplasty reported a 93% return to athletic activity for mosaicplasty.[18] For ACI, Mithoefer and associates[40] reported only 33% return to soccer. In a study of adolescent athletes undergoing ACI, only 60% returned to preinjury levels, although 96% reported good or excellent results and returned to high-impact sports at a limited level.[39]

In the present study, athletes returned to sport at an average of 9.6 months after osteochondral transplantation. This seems to be similar to reported return-to-sport times of 9.3 to 10 months for microfracture[5,48] and 6 to 9 months for autologous osteochondral grafts.[18,27] However, this is quicker than the average return-to-sport time reported for ACI of 18 months.[40] The relatively quick return-to-sport times for microfracture reported by Steadman et al[48] were in a cohort of National Football League players. Financial incentives to play and superior access to rehabilitation may have aided these professional athletes to return sooner. The technique of microfracture itself has an advantage in that it can be performed arthroscopically without an arthrotomy. The drawbacks include the prolonged period of nonweightbearing and the lack of durability of the fibrocartilage.[13,14,42] For osteochondral autografts, advantages include the rapid incorporation of autologous bone and an immediately functional hyaline articular cartilage surface.[21-23] However, this technique is limited by defect size, donor site morbidity, and fibrocartilage fill between the osteochondral plugs, which can be magnified in athletes who require higher biomechanical loads to be placed through the knee.[26] Autologous chondrocyte implantation has shown good durability,[37] but its disadvantages include its invasiveness, length of time required for the defect to fill, and high rate of obligate osteotomy for regenerate to form.[4] Efforts are currently directed at developing an arthroscopic technique for matrix-induced ACI, which would improve its invasiveness, especially in an athletic population.[1] In addition, recent data support a more aggressive rehabilitation approach in athletes undergoing second-generation ACI without compromising the clinical outcome at longer follow-up.[10] In a study of 31 competitive male athletes, 81% returned to their previous activity level at an average of 12 months with an intensive rehabilitation approach.[10] We attribute the relatively concise return-to-sport times in the current study of osteochondral allografts to patient selection, limited surgical morbidity with a small arthrotomy, and perhaps most importantly, patient-, lesion-, and sport-specific rehabilitation.[43] Specific advantages of the osteochondral allograft transplant are that it provides an immediately functional joint surface with hyaline articular cartilage and structural bone support, which permits early rehabilitation.

Age appeared to influence the ability to return to athletics in this study, which agrees well with previous studies. A reported age threshold for improved return to athletic competition appears to be between 25 and 40 years.[18,27,40] For microfracture, 65% of athletes younger than 40 years returned to sport compared with only 20% of older patients.[41] Similarly, for autologous mosaicplasty, 90% of athletes younger than 30 years returned to full competition, but only 23% of older patients returned to preinjury levels of sport.[27] Correspondingly, 71% of athletes younger than 25 years returned after ACI compared with only 29% of older patients.[40] Kish and colleagues[27] suggested that the lower return rate in older patients was attributed to a slower progression of postoperative rehabilitation. In the current study, it may be that few younger patients in this cohort had previously failed surgery, presented with a multiple operated knee, or had multiple defect locations within the knee. However, none of these factors were significant in multivariate analysis. Nevertheless, it is possible that older patients may simply discontinue their previous athletic activities.

In this study, a multivariable regression analysis adjusted for age, gender, and BMI showed that a longer preoperative duration of symptoms was a negative prognostic factor for returning to athletic activity. For microfracture, only 15% of athletes returned to sport if the time between diagnosis and surgical treatment was greater than 12 months compared to 66% for athletes with a shorter duration of preoperative symptoms.[41] After osteochondral autograft transfer, acute lesions fared better than chronic lesions, although no specific time threshold has been reported with this cartilage repair technique.[30] With the ACI technique, all adolescents with symptoms less than 1 year returned to sport compared to only 33% with preoperative symptoms more than 1 year.[39] Blevins and colleagues[5] have associated inferior volume of cartilage repair after the microfracture technique with a prolonged interval between injury and surgery, which may partially explain these results. Other authors have suggested that athletic and quadriceps deconditioning, thickened subchondral bone in chronic lesions, and expanding lesion margins all may play a role.[40,45]

This study has a number of limitations. It followed a relatively small cohort of patients with variable lengths of follow-up. Fresh osteochondral allograft transplantation is a relatively uncommon procedure, resulting in this limited patient group. Second, we established our minimum length of follow-up as 1 year. However, all patients included reported that they had either returned to full athletic participation or reached a plateau at most recent follow-up. A significant decline of athletic activity over time may occur with decreased athletic performance, increasing difficulty with activities of daily living, and early changes of osteoarthritis.[34] Longer follow-up is required to determine if these events occur in the athletes in the present series, as this study does not evaluate the durability of the grafts over time. Third, because we collected cases over a broad time period (2000-2010), our results may be skewed by evolving indications over that interval. Specifically, fresh osteochondral allografts were previously used as salvage procedures, in slightly older patients with multiple operated knees, which were considered unlikely to respond to more biologically demanding procedures like ACI and microfracture. Allografts are currently used at our institution in a younger group with fewer previous surgeries, as allografts are thought to give a more reliable functional result, especially when bone loss is present, in these highly active patients. Patients were indicated for primary cartilage restoration with osteochondral allograft for symptomatic focal chondral and osteochondral lesions of the knee greater than 2.5 cm^2 and without generalized osteoarthritis. This is in the treatment algorithm of several authors for lesions on the condyles.[2,8] Fourth, several of the patients in this series had concomitant injuries with the chondral lesion, potentially confounding the efficacy of the allograft transplantation. We elected to exclude patients who had undergone osteotomy at the time of allograft transplantation to off-load the cartilage lesion. Although the combined procedure has shown clear benefit, especially in the setting of misalignment, it is difficult to determine whether functional gains are attributable to the osteotomy or the allograft.[17,44] This is an important distinction because many case series of cartilage repair include patients with osteotomy or other procedures, resulting in a diminished ability to draw firm conclusions regarding efficacy. Lastly, 8 of the athletes in this series had a BMI over 30. The majority of these were well-trained collegiate athletes with an elevated muscle mass accounting for the increased BMI. In this series, we did not find a difference in the BMI between those who returned and did not return to sport (Table 3). Nonetheless, we do not advocate for any cartilage repair technique in the obese patient.

CONCLUSION

Osteochondral allograft transplantation for chondral and osteochondral defects in the knee in an athletic population allows for a high rate of return to sport. Risk factors for not returning to a full preinjury level of activity included age $\geq$25 years and preoperative duration of symptoms $\geq$12 months.

CONTRIBUTING AUTHORS

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