

# Meniscus transplantation in an active population with moderate to severe cartilage damage

Kevin R. Stone · Jonathan R. Pelsis · Scott T. Surette ·  
Ann W. Walgenbach · Thomas J. Turek

Received: 3 September 2013 / Accepted: 14 August 2014  
© European Society of Sports Traumatology, Knee Surgery, Arthroscopy (ESSKA) 2014

## Abstract

**Purpose** The purpose of this study was to evaluate the efficacy of meniscus allograft transplantation in an active patient population with moderate to severe cartilage damage and the procedure's ability to allow sports participation postoperatively.

**Methods** Forty-nine patients with moderate to severe cartilage damage who underwent meniscus allograft transplantation were included in this study; those with symptoms related to articular cartilage damage also underwent articular cartilage repair. Kaplan–Meier (KM) survival estimate, potential hazards to survival, and subjective clinical outcomes were analyzed. For KM survival, failure was defined as progression to knee arthroplasty, surgical removal of the meniscus transplant without revision, a self-reported follow-up pain level that was more than preoperative level, or constant moderate pain with no relief from non-operative treatment.

**Results** The mean follow-up time was  $8.6 \pm 4.2$  years. The mean age at surgery was  $45.3 \pm 12.9$  years. Meniscus transplantation was performed in 37 medial cases and 12 lateral cases. There were 41 patients with Outerbridge Grade IV and 8 with Grade III. Thirty-six (73.5 %) patients were able to participate in sporting activities postoperatively. Eleven (22.4 %) meniscus transplants failed at an average of  $5.2 \pm 4.4$  years. The KM mean estimated survival time was  $12.6 \pm 0.7$  years. No tested risks were found to affect sports participation or procedure success.

**Conclusions** Meniscus transplantation is a viable surgical option for patients with severe cartilage damage and missing or irreparable menisci to provide significant improvements in pain and function levels in the medium to long term with the majority of patients achieving their goal of participation in sporting activities. These results indicate that symptomatic patients may be able to participate in sports activities for an average of 12.6 years following meniscus transplantation.

**Level of evidence** Case series, Level IV.

**Keywords** Meniscus allograft transplantation · Osteoarthritis · Cartilage repair · Sports

## Introduction

The meniscus is a unique cartilage structure that is involved in shock absorption, stabilization, lubrication, and load distribution within the knee [4, 7, 9–11, 14, 17, 18, 26]. Tears to this tissue are a common knee injury with an estimated annual incidence of 60–70 per 100,000 [6, 13]. Meniscus allograft transplantation has been reported to reduce pain and improve function and activity levels for patients with irreparable meniscal tears [2, 5, 12, 15, 16, 19, 22, 24, 25, 27]. However, the literature does not address the success of this procedure for patients who have missing or irreparable menisci combined with severe articular cartilage damage and want to participate in sporting activities. The purpose of this study was to report the outcomes of meniscus allograft transplantation in an active arthritic population and to evaluate the procedure's clinical efficacy and its ability to allow these patients to participate in sporting activities postoperatively. It was hypothesized that meniscus transplantation would provide significant improvements in pain

K. R. Stone (✉) · J. R. Pelsis · S. T. Surette ·  
A. W. Walgenbach · T. J. Turek  
Stone Research Foundation, San Francisco, CA, USA  
e-mail: kstonemd@stoneclinic.com

K. R. Stone · A. W. Walgenbach  
The Stone Clinic, San Francisco, CA, USA

and function levels as measured by validated subjective outcome tools while permitting participation in sports.

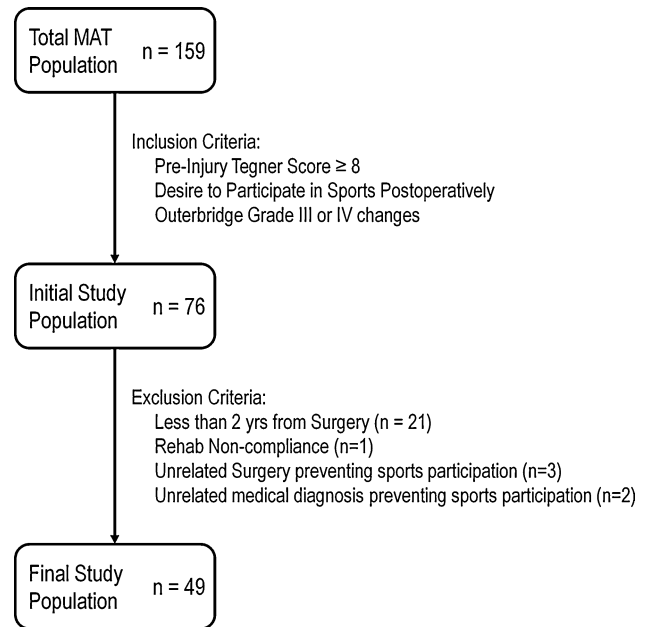
## Materials and methods

Prior to undergoing meniscus transplantation, all patients underwent an informed consent process approved by an independent institutional review board in order for their data to be entered into a prospective database. Patients were then asked to complete the International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC) [8], Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) form [1], and the Tegner Activity Level Scale [23]. Additionally, patients were asked to report the pain level experienced over the previous 48 hours on a 5-point scale (0 = none, 1 = mild, 2 = moderate, 3 = severe, and 4 = extreme), based on the WOMAC scoring scale.

Patients were selected from the database for inclusion in this study if, prior to their injury, they participated in competitive sports. Participation in sports was verified by preinjury Tegner scores, using a minimum score of 8. The Tegner scores of 8 and greater correspond to competitive participation in soccer, football, rugby, ice hockey, wrestling, squash, badminton, track and field, or down-hill skiing. Additional selection criteria were as follows: Prior to undergoing surgery, patients reported a desire to participate in one or more sporting activities postoperatively and at the time of surgery they were identified as having Outerbridge (OB) Grade III or Grade IV changes to the articular cartilage in the compartment undergoing meniscus transplantation. Seventy-six patients met these initial inclusion criteria. Patients were excluded if they were <2 years from meniscus transplantation ( $n = 21$ ); non-compliant with the postoperative rehabilitation protocol ( $n = 1$ ); undergoing orthopedic surgery on an unrelated joint which prohibited participation in sporting activities ( $n = 3$ ); or were diagnosed with severe non-orthopedic medical issues prohibiting sporting activities ( $n = 2$ ). Using these criteria, a total of 49 patients were included in the final study population (Fig. 1).

## Surgical technique

Meniscus allograft transplantation was performed arthroscopically using the three-tunnel technique [21]. While a medial meniscus transplant used periosteum, not bone blocks at both horns, a lateral meniscus transplant procedure preserved the bony block between the horns, inserting it into a trough made on the tibial plateau. Damage to the articular cartilage was classified using the OB scoring system during the surgical procedure. As indicated, articular



**Fig. 1** Patient data were entered prospectively into an IRB-approved database. For this study, study subjects were selected from the total enrolled meniscus transplantation population using the criteria described above

cartilage lesions were treated as follows: Grade III lesions were treated with microfracture alone; Grade IV defects either  $\leq 25$  mm<sup>2</sup>, located too far posteriorly (inaccessible with the trephine), or directly under the meniscal allograft transplant on the tibial side were treated with microfracture as well; and articular cartilage paste grafting [20] was used to treat Grade IV defects  $>25$  mm<sup>2</sup> that were accessible. The exposed bone area was morselized through extensive microfracture. Next, an 8 mm  $\times$  15 mm plug of articular cartilage and cancellous bone was harvested from the intercondylar notch and smashed into a paste. The paste was then impacted into the morselized defect. Prior to 2003, at the time of meniscal allograft transplantation, medial opening wedge osteotomies ( $n = 6$ ) were performed using a resorbable osteotomy wedge (Bionx, Blue Bell, Pennsylvania) for correction of varus malalignment ranging between 5° and 14°. At the discretion of the senior author, meniscal allograft transplantation procedures were performed without osteotomies after this. Concomitant ACL reconstruction was indicated and performed at the time of meniscus transplantation for 4 patients.

## Postoperative rehabilitation

All patients were discharged from the outpatient surgery center on the day of surgery with a knee brace limiting range of motion between 0° and 90°. A rehabilitation program commenced the day after surgery starting with soft

tissue mobilization, non-operative leg bicycling, cryotherapy, and range of motion exercises. Aerobic exercise was initiated early based on the positive effects of whole-body exercise on wound healing [3]. Full weight bearing was introduced at 4 weeks in a moderate protective phase until the 12th week.

### Follow-up

All patients undergoing meniscus allograft transplantation were contacted for follow-up and asked to complete IKDC, WOMAC, Tegner, and pain questionnaires at 2, 3, 5, 7, 10, 15, and every subsequent 5 years postoperatively. Failure of the meniscus transplant was defined as progression to knee arthroplasty, surgical removal of the meniscus transplant without revision, a self-reported follow-up pain level that was more than preoperative level, or constant moderate pain with no relief from non-operative treatment.

### Statistical analysis

Variables were tested for normal distribution by the Kolmogorov–Smirnov test. Continuous variables are presented as mean  $\pm$  standard deviation; categorical variables as number and percentage; and non-normally distributed variables as median and interquartile (IQR) range. The change in temporal subjective outcome measures was analyzed first by Kruskal–Wallis  $H$  test. Analysis of the difference in median scores at the different postoperative time points compared with pre-op was then carried out using the Mann–Whitney  $U$  test with a power level of 0.97. To protect the family-wise type I error rate, Hochberg’s step-up method was implemented to adjust the rejection criteria of the individual Mann–Whitney  $U$  tests. To better understand the expected lifespan of the meniscus allograft in this population, mean and median estimated meniscus allograft survival were calculated using Kaplan–Meier product analysis (KM). Risks of failure of the meniscus transplant and hazards to patients’ ability to participate in sporting activities postoperatively were analyzed using the chi-squared test. Data analysis was performed using SPSS 21.0 (IBM Corporation, Armonk, New York). Global significance was set at  $\alpha = 0.05$  for all tests.

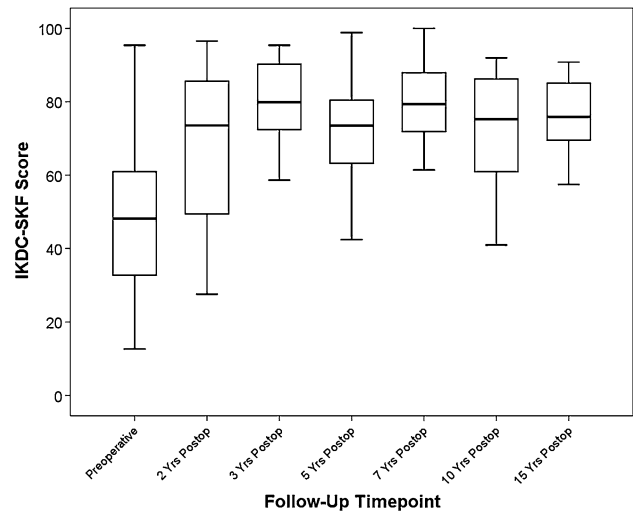
### Results

Table 1 summarizes the demographics of the patients. The mean time from surgery to the most recent evaluation was  $8.6 \pm 4.2$  years (range 2.0–15.0 years). OB classification of patients’ articular cartilage changes at the time of surgery was as follows: 41 (83.7 %) Grade IV; and 8 (16.3 %) Grade III. Thirty-four (69.4 %) patients

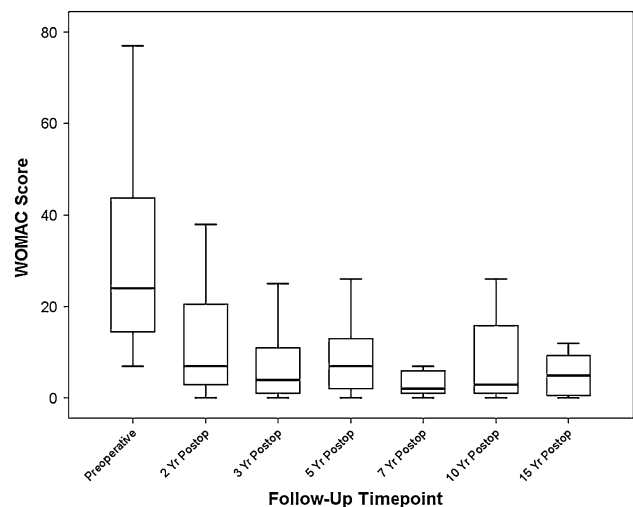
**Table 1** Demographics of patients

	Mean (range) or $n$ (%)
Male	36/49 (73.5)
Female	13/49 (26.5)
Age at surgery	45.3 (14.1–73.2)
Medial allograft	37/49 (75.5)
Lateral allograft	12/49 (24.5)
Time from injury to surgery (years)	13.8 (0.6–39.7)
Follow-up (years)	8.6 (2.0–15.0)

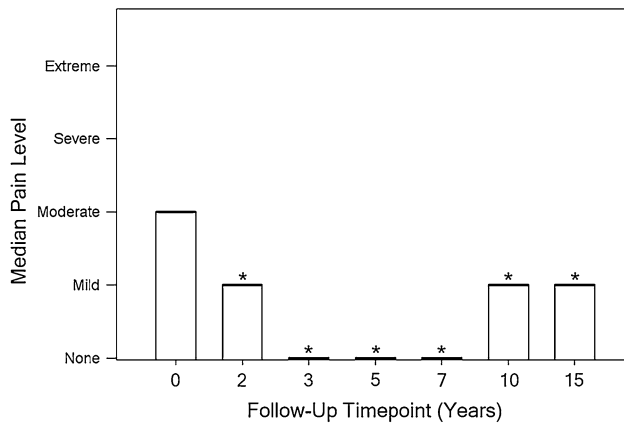
*SD* standard deviation



**Fig. 2** Median IKDC score was significantly higher at 2 year ( $p < 0.001$ ), 3 year ( $p < 0.001$ ), 5 year ( $p < 0.001$ ), 7 year ( $p < 0.001$ ), 10 year ( $p < 0.001$ ), and 15 year ( $p = 0.001$ ) follow-up time points than prior to primary meniscus allograft transplantation



**Fig. 3** Median WOMAC score was significantly lower at 2 year ( $p < 0.001$ ), 3 year ( $p < 0.001$ ), 5 year ( $p < 0.001$ ), 7 year ( $p < 0.001$ ), 10 year ( $p < 0.001$ ), and 15 year ( $p < 0.001$ ) follow-up time points than prior to primary meniscus allograft transplantation

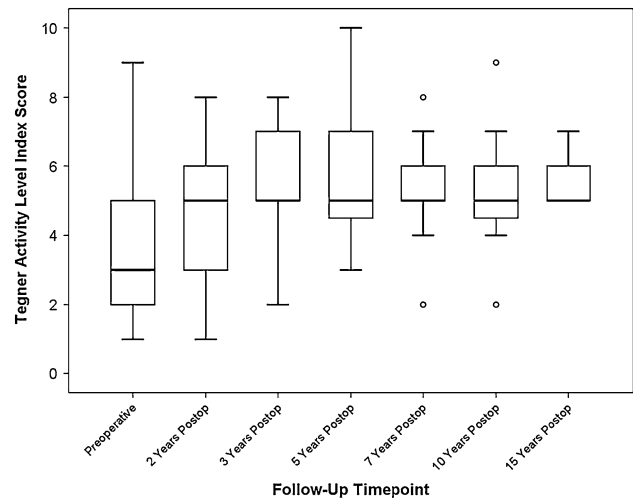


**Fig. 4** Median self-reported pain score was significantly lower at 2 year ( $p < 0.001$ ), 3 year ( $p < 0.001$ ), 5 year ( $p < 0.001$ ), 7 year ( $p < 0.001$ ), 10 year ( $p = 0.005$ ), and 15 year ( $p = 0.007$ ) follow-up time points than prior to primary meniscus allograft transplantation

underwent simultaneous articular cartilage repair. Eleven of the 34 (32.4 %) underwent microfracture alone, 10 of the 34 (29.4 %) underwent articular cartilage paste grafting alone, and 13 of the 34 (38.2 %) underwent a combination of articular cartilage paste grafting and microfracture. Of the 15 patients not undergoing simultaneous articular cartilage repair, 11 (73.3 %) underwent cartilage repair in a separate procedure at the discretion of the senior author. Staging of this procedure is now preferred by our clinic. The cartilage repair procedure is performed 6 weeks before the meniscus allograft in order to apply continuous passive motion. The remaining 4 (26.7 %) patients had OB Grade III changes without exposed bone or symptoms, and therefore, it was elected not to perform a cartilage repair procedure. All four of these patients were able to participate in sporting activities postoperatively and had intact meniscus transplants at latest follow-up. Additionally, no cartilage repair was necessary at any point during the follow-up period.

Figures 2, 3, and 4 show sustained significant improvements in IKDC, WOMAC, and self-reported pain scores, respectively, throughout the postoperative follow-up period as compared with preoperative scores. Thirty-six (73.5 %) of the patients were able to participate in sporting activities following meniscus transplantation. Tegner scores were significantly improved from the median preoperative value starting at 3 years postoperatively (Fig. 5). The hazards to postoperative participation in sporting activities are summarized in Table 2.

Sixteen (32.7 %) of the patients required additional surgical treatment of the meniscus allograft including a combination of partial meniscectomy ( $n = 10$ ), suture repair ( $n = 4$ ), and revision meniscus allograft transplantation ( $n = 5$ ) (Table 3). One patient undergoing only partial



**Fig. 5** Median Tegner activity level was significantly higher at 3 year ( $p = 0.006$ ), 5 year ( $p = 0.010$ ), 7 year ( $p = 0.024$ ), 10 year ( $p = 0.024$ ), and 15 year ( $p = 0.032$ ) follow-up time points than prior to primary meniscus allograft transplantation, but was not significantly higher at the 2 year ( $p = 0.089$ ) time point

**Table 2** Meniscus transplantation results and hazards summary

	Failed	Intact	<i>p</i> value
Age (years, mean)	46.5	44.8	0.198 (n.s.)
Time from injury to surgery (years, mean)	14.3	13.6	0.865 (n.s.)
Highest postoperative Tegner score (median)	5.5	6.0	0.590 (n.s.)
Operative compartment	Medial	Lateral	<i>p</i> value
Failure rate (%)	27.0	41.7	1.000 (n.s.)
Articular cartilage repair performed	Yes	No	<i>p</i> value
Failure rate (%)	29.4	33.3	1.000 (n.s.)
	Sports	No sports	<i>p</i> value
Age (years, mean)	45.2	45.9	0.988 (n.s.)
Time from injury to surgery (years, mean)	14.4	10.5	0.391 (n.s.)
Operative compartment	Medial	Lateral	<i>p</i> value
Participation in sports (%)	86.5	75.0	0.533 (n.s.)
Articular cartilage repair performed	Yes	No	<i>p</i> value
Participation in sports (%)	85.3	80.0	0.533 (n.s.)

meniscectomy had the meniscus allograft removed after 1.9 years. For the five meniscus transplants (10.2 %) that were removed and a revision meniscus transplantation was performed, only one underwent revision transplantation

**Table 3** Additional meniscus-related procedures

Patients ( <i>n</i> )	Reoperation		
	First	Second	Third
7	PM		
3	SR		
2	PM	RT	
1	RT		
1	SR	RT	SR
1	RT	RT	
1	PM	SR	

PM partial meniscectomy, SR suture repair, RT revision transplantation

**Table 4** Meniscus transplant failures

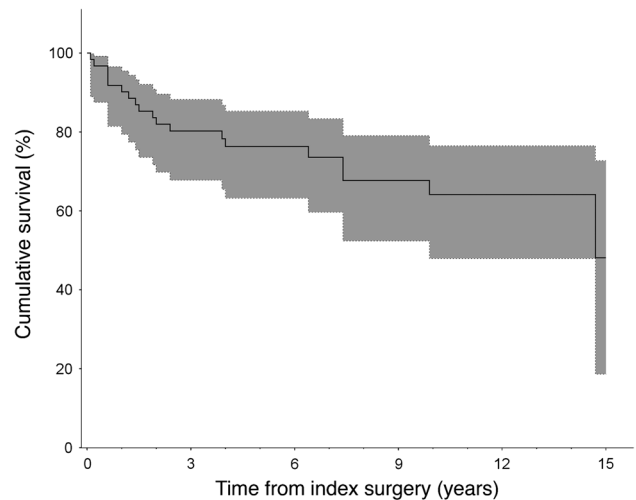
Reason for failure	Patients ( <i>n</i> )
Uncorrected pain	2
Allograft Removed	5
Unicondylar arthroplasty	3
Total knee arthroplasty	1
<b>Total transplant failures</b>	<b>11</b>

for uncorrected pain and was counted as a failure. Four (80.0 %) of the five patients underwent revision transplantation for sports-induced traumas and were not counted as failures as they were still intact at the end of follow-up. Three of them reported successful participation in sporting activities following revision transplantation and one reported no pain in normal daily activities.

Eleven (22.4 %) meniscus transplants failed between 1.4 and 14.7 years at an average of  $5.2 \pm 4.4$  years (Table 4). The KM estimate of the survival function is shown in Fig. 6. The KM mean estimated survival time was  $12.6 \pm 0.7$  years (95 % CI 11.2–14.0 years). The risks of meniscus allograft failure are summarized in Table 2. Medial meniscus transplantation had a higher success rate (73.0 %) than lateral meniscus transplantation (58.3 %) in this study. However, hazard analysis did not find the operative compartment to be a significant hazard on the time to procedure failure.

## Discussion

In this series of patients with severe cartilage damage, 73.5 % were able to participate in sporting activities following meniscus transplantation. Median Tegner scores collected postoperatively showed sustained improvement in activity levels post-meniscus transplantation without an adverse effect on procedure success. The critical roles of



**Fig. 6** The Kaplan–Meier (KM) mean estimated survival time based on the study population of 49 patients was  $12.6 \pm 0.7$  years (95 % CI 11.2–14.0 years). 95 % confidence intervals for the KM survival curve are shown as the shaded area between the dashed lines

the meniscus have led us to take an aggressive approach to performing meniscus transplantation in patients with missing or irreparably damaged menisci and high-grade changes to their articular cartilage. Patients wishing to participate in sporting activities post-meniscus transplantation test the limits of surgical success, placing high demands on their knees and thus on a transplanted meniscus.

Traditional thinking has been to avoid meniscus transplantation in the setting of articular cartilage defects due to decreased predictability of the results. Promising results of meniscus transplantation in combination with articular cartilage repair now expand the indication for the procedure provided that the cartilage damage is addressed as well [2, 15, 19, 24]. It has been well documented that compromised menisci often lead to arthritic changes in the articular cartilage. In this population of patients, the average time from injury to meniscus transplantation surgery was 13.8 years and 83.7 % presented with OB Grade IV changes to their articular cartilage. The failure rate of meniscus transplantation was higher in patients who did not undergo concomitant articular cartilage repair (33.3 vs. 29.4 %). However, the necessity of performing articular cartilage repair was not found to significantly affect the time to procedure failure or ability to participate in sporting activities.

The failure rate in this study was 22.4 % with an average follow-up time of 8.6 years and an average time to failure of 5.2 years. The results appear to be comparable with other studies where meniscus allograft transplantation was performed in the setting of severe cartilage damage. In a series of 115 meniscus transplantation patients with OB Grade III and IV cartilage changes, Stone et al.

[19] reported a failure rate of 20.1 % at an average follow-up of 5.8 years. Verdonk et al. [24] reported on a series of 100 patients with normal to severely degenerated cartilage undergoing meniscus transplantation with a failure rate of 21 % at an average follow-up of 7.2 years.

Limitations of this study include population bias considering all subjects were highly motivated to request biologic reconstruction of the knee rather than arthroplasty and were consequently equally motivated to participate in sporting activities. Additionally, the diversity of the patient population with regard to age and time from initial injury makes statistically comparing patients and determining an isolated effect of the meniscus transplantation challenging. However, neither age nor time from injury to surgery had a significant effect on the outcome of meniscus transplantation. A further limitation of this study is the inclusion of only one surgical technique analyzed in a retrospective manner. Nevertheless, the results suggest that meniscus transplantation is a viable surgical option for patients with cartilage damage and missing or irreparable menisci to provide significant improvements in pain and function levels in the medium to long term with the majority of patients achieving their goal of participation in sporting activities. This study may serve as a useful guide for surgeons when counseling their patients on sports participation after meniscus allograft transplantation. These results indicate that symptomatic patients may be able to participate in sports activities for an average of 12.6 years following meniscus transplantation.

## Conclusion

Meniscus transplantation is a viable surgical option for patients with moderate to severe cartilage damage and missing or irreparable menisci who are motivated to participate in sports. In this population, the procedure provided significant improvements in pain and function levels in the medium to long term with the majority of patients achieving their goal of participation in sporting activities.

## References

- Bellamy N, Buchanan WW, Goldsmith CH, Campbell J, Stitt LW (1988) Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. *J Rheumatol* 15(12):1833–1840
- Cole BJ, Dennis MG, Lee SJ, Nho SJ, Kalsi RS, Hayden JK, Verma NN (2006) Prospective evaluation of allograft meniscus transplantation: a minimum 2-year follow-up. *Am J Sports Med* 34(6):919–927
- Emery CF, Kiecolt-Glaser JK, Glaser R, Malarkey WB, Frid DJ (2005) Exercise accelerates wound healing among healthy older adults: a preliminary investigation. *J Gerontol A Biol Sci Med Sci* 60(11):1432–1436
- Fairbank TJ (1948) Knee joint changes after meniscectomy. *J Bone Joint Surg Br* 30B(4):664–670
- Farr J, Rawal A, Marberry KM (2007) Concomitant meniscal allograft transplantation and autologous chondrocyte implantation: minimum 2-year follow-up. *Am J Sports Med* 35(9):1459–1466
- Hede A, Jensen DB, Blyme P, Sonne-Holm S (1990) Epidemiology of meniscal lesions in the knee. 1,215 open operations in Copenhagen 1982–84. *Acta Orthop Scand* 61(5):435–437
- Henning CE, Lynch MA (1985) Current concepts of meniscal function and pathology. *Clin Sports Med* 4(2):259–265
- Irrgang JJ, Anderson AF, Boland AL, Harner CD, Kurosaka M, Neyret P, Richmond JC, Shelborne KD (2001) Development and validation of the international knee documentation committee subjective knee form. *Am J Sports Med* 29(5):600–613
- Krause WR, Pope MH, Johnson RJ, Wilder DG (1976) Mechanical changes in the knee after meniscectomy. *J Bone Joint Surg Am* 58(5):599–604
- Levy IM, Torzilli PA, Gould JD, Warren RF (1989) The effect of lateral meniscectomy on motion of the knee. *J Bone Joint Surg Am* 71(3):401–406
- Levy IM, Torzilli PA, Warren RF (1982) The effect of medial meniscectomy on anterior-posterior motion of the knee. *J Bone Joint Surg Am* 64(6):883–888
- Marcacci M, Marcheggiani Muccioli GM, Grassi A, Ricci M, Tsapralis K, Nanni G, Bonanzinga T, Zaffagnini S (2014) Arthroscopic meniscus allograft transplantation in male professional soccer players: a 36-month follow-up study. *Am J Sports Med* 42(2):382–388
- Nielsen AB, Yde J (1991) Epidemiology of acute knee injuries: a prospective hospital investigation. *J Trauma* 31(12):1644–1648
- Noble J, Turner PG (1986) The function, pathology, and surgery of the meniscus. *Clin Orthop Relat Res* 210:62–68
- Rue LJPH, Yanke AB, Busam ML, McNickle AG, Cole BJ (2008) Prospective evaluation of concurrent meniscus transplantation and articular cartilage repair: minimum 2-year follow-up. *Am J Sports Med* 36(9):1770–1778
- Saltzman BM, Bajaj S, Salata M, Daley EL, Strauss E, Verma N, Cole BJ (2012) Prospective long-term evaluation of meniscal allograft transplantation procedure: a minimum of 7-year follow-up. *J Knee Surg* 25(2):165–175
- Seedhom BB (1976) Loadbearing function of the menisci. *Physiotherapy* 62(7):223
- Seedhom BB (1979) Transmission of the load in the knee joint with special reference to the role of the meniscus. Part I + II. *Eng Med* 8(4):220–228
- Stone KR, Adelson WS, Pelsis JR, Walgenbach AW, Turek TJ (2010) Long-term survival of concurrent meniscus allograft transplantation and repair of the articular cartilage: a prospective two- to 12-year follow-up report. *J Bone Joint Surg Br* 92-B(7):941–948
- Stone KR, Walgenbach AW (1997) Surgical technique for articular cartilage transplantation to full thickness cartilage defects in the knee joint. *Oper Tech Orthop* 7(4):7
- Stone KR, Walgenbach AW (2003) Meniscal allografting: the three-tunnel technique. *Arthroscopy* 19(4):426–430
- Stone KR, Walgenbach AW, Turek TJ, Freyer A, Hill MD (2006) Meniscus allograft survival in patients with moderate to severe unicompartmental arthritis: a 2- to 7-year follow-up. *Arthroscopy* 22(5):469–478
- Tegner Y, Lysholm J (1985) Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat Res* 198:43–49
- Verdonk PC, Demurie A, Almqvist KF, Veys EM, Verbruggen G, Verdonk R (2005) Transplantation of viable meniscal allograft.

- Survivorship analysis and clinical outcome of one hundred cases. *J Bone Joint Surg Am* 87(4):715–724
25. Vundelinckx B, Vanlauwe J, Bellemans J (2014) Long-term subjective, clinical, and radiographic outcome evaluation of meniscal allograft transplantation in the knee. *Am J Sports Med* 42(7):1592–1599
  26. Walker PS, Erkman MJ (1975) The role of the menisci in force transmission across the knee. *Clin Orthop Relat Res* 109:184–192
  27. Zhang H, Liu X, Wei Y, Hong L, Geng XS, Wang XS, Zhang J, Cheng KB, Feng H (2012) Meniscal allograft transplantation in isolated and combined surgery. *Knee Surg Sports Traumatol Arthrosc* 20(2):281–289