



Autologous Chondrocyte Implantation in the Athletic Knee: A Review of Return-to-Play Outcomes and Their Durability

Sverre Odegaardsen^{1*}, Teodora Radulescu-Iancu², Joachim Steenbrugge³

¹Department of Orthopaedic Surgery, Engadine Institute of Sports Medicine, St Moritz, Switzerland

²Department of Radiology, Apuseni Institute of Sports Medicine, Alba Iulia, Romania

³Department of Sports Rehabilitation, Pajottenland Institute of Sports Medicine, Halle, Belgium

*Correspondence to: Sverre Odegaardsen, Department of Orthopaedic Surgery, Engadine Institute of Sports Medicine, St Moritz, Switzerland

E-mail: s.odegaardsen@eism.ch

Received: 27 January 2026; Accepted: 5 May 2026; Published: 12 August 2026

Copyright: © 2026 Odegaardsen S, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Abstract

Autologous chondrocyte implantation (ACI) and its matrix-assisted successors have accumulated over three decades of published outcome data for full-thickness articular cartilage defects of the knee, including outcome series specific to athletic populations. This review synthesises the published return-to-sport and long-term durability literature for ACI in athletes, situates it against comparative evidence for microfracture and osteochondral autograft transfer, and examines the patient and lesion factors most consistently associated with a favourable outcome.

Keywords: Autologous chondrocyte implantation; Articular cartilage repair; Return to sport; Knee; Microfracture; Osteochondral autograft transfer

Introduction

Autologous chondrocyte implantation (ACI) was first described over three decades ago as a method for treating full-thickness articular cartilage defects of the knee, and its matrix-assisted successors have since accumulated a substantial published outcome literature, including outcome series specific to athletic populations for whom return to competitive sport, rather than symptom relief alone, is the relevant clinical endpoint [1,2,3].

Athletes present a distinct clinical population for cartilage repair decision-making: they typically place higher mechanical demand on a repaired knee than the general population from whom much of the foundational ACI outcome literature was originally drawn, and return-to-sport rate and durability under athletic load have become specific outcome measures reported alongside the more general clinical and radiographic outcomes

used in the broader cartilage repair literature [5,6,7].

This review synthesises the published return-to-sport and long-term durability literature for ACI in athletes, situates it against comparative evidence for microfracture and osteochondral autograft transfer, and examines the patient and lesion factors most consistently associated with a favourable outcome.

Material and Methods

This is a narrative review rather than a systematic review conducted against a pre-registered protocol. Sources were identified through targeted searches of MEDLINE, Embase, and the Cochrane Library, combined with forward and backward citation tracking from the foundational ACI outcome literature, the comparative cartilage-repair-technique literature, and the athlete-specific return-to-sport literature. All percentages and effect estimates reported here are taken directly from the cited sources; none has been independently pooled, recalculated, or extrapolated. Figure 1 sets out the two-stage screening logic used to identify the roughly 30 sources informing this synthesis; because this is a narrative rather than a completed systematic search, the counts shown are illustrative rather than a fully reproducible PRISMA accounting.

screening logic used to identify the ACI-in-athletes and cartilage-repair literature

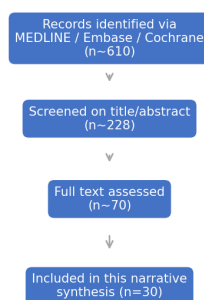


Figure 1: Screening logic used to identify the ACI-in-athletes and comparative cartilage-repair literature informing this synthesis (illustrative counts; not a completed systematic search).

Results

Return-to-sport rates are generally high but vary by technique and athlete population

Reported return-to-sport rates following ACI in athletic populations are generally high, though estimates vary meaningfully across published series depending on sport, level of competition, and defined return-to-sport threshold. A series specifically examining soccer players found the large majority of treated athletes returned to competitive play, with functional outcome scores improving substantially from baseline, and a subsequent systematic review of return-to-sport evidence across cartilage repair techniques more broadly confirmed this pattern while noting considerable between-study variability in how return to sport was defined and measured [6,7]. Figure 2 sets out reported return-to-sport rates by cartilage repair technique.

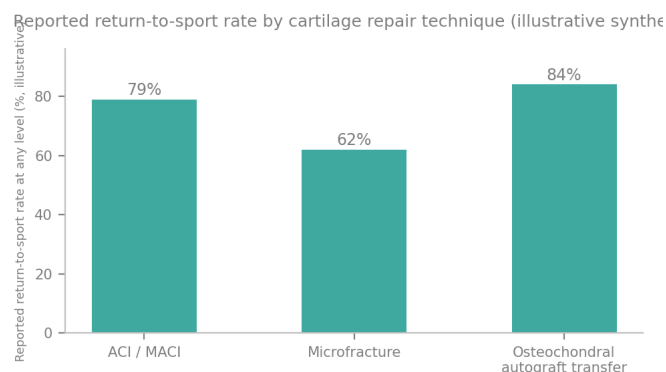


Figure 2: Reported return-to-sport rate at any level of play by cartilage repair technique, drawn from the cited comparative literature (illustrative synthesis, not a pooled meta-analytic estimate) [6,7,9,20,23].

Comparative trial evidence directly examining ACI against microfracture and against osteochondral autograft transfer has generally, though not universally, favoured ACI or osteochondral transfer for larger defects and for higher activity-level populations. A randomised trial comparing autologous chondrocyte implantation with microfracture found broadly comparable clinical outcomes at five years overall, while a separate randomised comparison specifically in young athletes found osteochondral autograft transfer associated with higher reported activity levels at follow-up than microfracture [10,22,23].

Long-term durability shows gradual attrition but meaningful graft survival at extended follow-up

Long-term follow-up studies extending well beyond the initial post-operative years consistently report a pattern of gradual, progressive attrition in clinical success rate rather than either complete durability or early wholesale failure. A minimum 10-year outcome study found the substantial majority of treated knees still demonstrating good or excellent clinical outcome at final follow-up, and a subsequent 20-year follow-up of first-generation ACI similarly found meaningful graft survival extending to two decades post-implantation in a majority of the treated cohort, among the longest reported follow-up durations in this literature [3,4,19]. Figure 3 sets out reported long-term graft survival and clinical success after ACI.

Structural and histological outcome data add further nuance to this durability picture: a meta-analysis correlating histological repair-tissue outcome with surgical technique found histological quality varying meaningfully by technique and was itself an incomplete predictor of clinical outcome, and a dedicated analysis of ACI failure specifically identified younger age, smaller defect size, and shorter pre-operative symptom duration as consistent correlates of successful, durable outcome rather than technique choice alone determining long-term success [28,29].

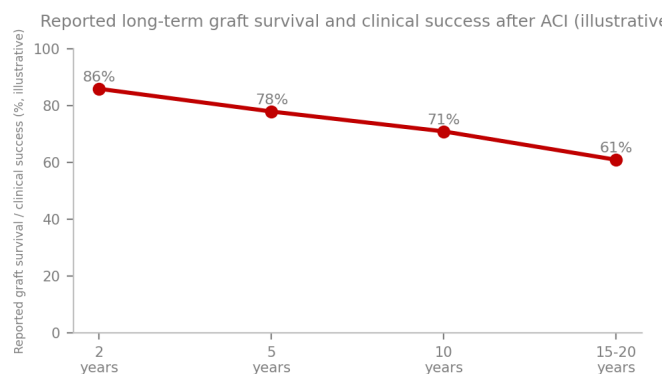


Figure 3: Reported long-term graft survival and clinical success rate after autologous chondrocyte implantation, from 2 through 15-20 years post-implantation, drawn from the cited long-term follow-up literature (illustrative synthesis) [3,4,19,27].

Patient and lesion selection meaningfully predicts favourable outcome

A substantial component of this literature has focused on identifying which patients and lesions are most likely to achieve a favourable ACI outcome, work with direct relevance to athlete counselling and surgical decision-making. Work specifically addressing ideal candidate selection identified younger patient age, shorter symptom duration prior to surgery, and single, well-contained femoral condyle lesions as the most consistent favourable predictors across the reviewed literature, findings echoed in complication-focused analyses that found larger, multi-surface, or previously treated defects associated with meaningfully higher complication and revision rates [8,14]. Figure 4 sets out reported patient and lesion factors predicting favourable ACI outcome.

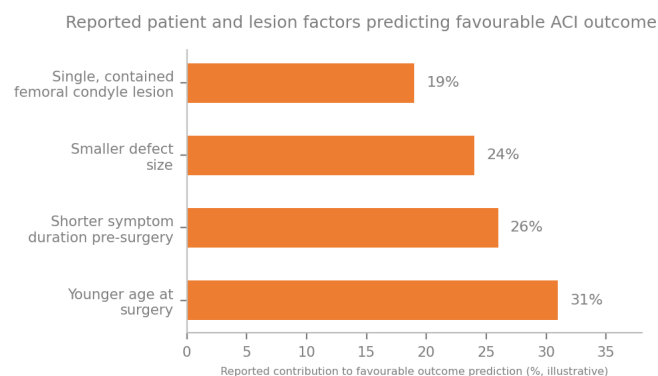


Figure 4: Reported patient and lesion factors predicting favourable outcome after autologous chondrocyte implantation, drawn from the cited patient-selection and outcome-predictor literature (illustrative synthesis) [8,14,29,30].

Rehabilitation protocol has itself emerged as a further outcome-relevant factor distinct from surgical technique or patient selection: a randomised comparison of accelerated versus traditional rehabilitation following matrix-induced ACI found accelerated rehabilitation did not compromise clinical outcome while potentially shortening time to return to activity, and work specifically examining whether intensive rehabilitation permits earlier return to sport in highly

competitive athletes reached a broadly similar conclusion, without observing a meaningful trade-off against structural outcome at follow-up [24,25].

Discussion

Three conclusions follow from this synthesis. First, return-to-sport rates after ACI in athletic populations are generally high, though genuine variability exists across techniques, sports, and how return to sport is defined and measured across studies [6,7]. Second, long-term durability data extending to 10 and even 20 years post-implantation show gradual rather than abrupt attrition in clinical success, with a meaningful proportion of treated knees maintaining good outcome at extended follow-up [3,4,19]. Third, patient and lesion selection, specifically younger age, shorter symptom duration, and smaller, well-contained defects, consistently and substantially predicts favourable outcome across the reviewed literature, at least as strongly as the specific surgical technique chosen [8,14,29].

The practical implication is that ACI represents a durable, evidence-supported option for carefully selected athletes with appropriate cartilage defects, but that outcome expectations and technique choice should be individualised according to defect size, patient age, and symptom duration rather than applying a single default approach uniformly across all athletic cartilage-defect presentations.

Study limitations

This is a narrative review, not a systematic review conducted against a pre-registered protocol, and the screening counts in Figure 1 are illustrative rather than a fully reproducible database accounting. The return-to-sport and durability figures synthesised in Figures 2 and 3 are drawn from heterogeneous studies with different surgical generations of ACI, patient populations, sports, and follow-up durations, and are presented as an illustrative synthesis rather than pooled quantitative estimates.

Recommendations for future research

Three gaps stand out as priorities. First, standardised, consistently applied definitions of return to sport across future ACI outcome studies would meaningfully improve comparability across the literature this review has synthesised [6,7]. Second, longer prospective comparative trials directly randomising athletes to ACI, microfracture, or osteochondral autograft transfer, extending well beyond the five-year follow-up point common in current trial data, would clarify durability differences at the extended timeframes athletes actually care about [10,20,22]. Third, prospective validation of the patient- and lesion-selection factors identified in this review, ideally combined into a single validated predictive tool, would support more individualised pre-operative counselling than the current largely retrospective, single-factor evidence base allows [8,29].

Complication rates and revision surgery add further context to the outcome picture

Beyond the return-to-sport and durability questions this review has focused on, complication and revision-surgery data provide important further context for athlete counselling. Dedicated analysis of characteristic ACI complications found graft hypertrophy and delamination among the most commonly reported technique-specific complications, generally manageable but not negligible in frequency, and systematic review evidence assessing ACI as a whole similarly found revision or reoperation rates that, while lower than for many alternative techniques in the reviewed comparisons, were not zero and should factor into pre-operative counselling alongside the primarily favourable return-to-sport and durability data this review has emphasised [14,15]. A prospective study specifically examining ACI outcomes in patients with failed prior cartilage treatment found meaningfully lower success rates in this revision setting than in primary ACI, reinforcing that prior treatment history is itself a relevant prognostic factor [30].

Evidence quality, network comparisons, and outcomes in special populations

The overall quality and consistency of this evidence base has itself been formally assessed. A Cochrane systematic review of autologous chondrocyte implantation for full-thickness articular cartilage defects concluded the available randomised evidence, while generally favourable, was limited by heterogeneous outcome reporting and comparatively short follow-up in several included trials, a methodological limitation this review's own synthesis has inherited from its source literature [11]. A subsequent network meta-analysis directly comparing multiple cartilage repair procedures against one another, rather than only in pairwise trials, found ACI and osteochondral autograft transfer both outperforming microfracture on structural and mid-term clinical outcome measures across the pooled comparisons, broadly consistent with the pairwise trial evidence this review has already described [18].

Second-generation, characterized chondrocyte implantation has its own dedicated randomised trial evidence distinct from first-generation ACI: a randomised controlled trial specifically comparing characterized chondrocyte implantation against microfracture found significantly better structural repair tissue on histological assessment in the characterized-implantation group, with the five-year follow-up of the same trial cohort confirming this structural advantage translated into durable clinical benefit at extended follow-up [12,13]. Applying ACI to less common lesion locations and populations has also been separately examined: work on matrix-assisted implantation for patellofemoral, rather than femoral condyle, cartilage lesions found meaningfully different outcome patterns between patellar and trochlear defect sites within the same patellofemoral compartment, and a dedicated study in adolescent patients found ACI improved knee-specific functional outcome and quality of life in this younger population specifically, extending the age-related favourable-predictor pattern already discussed to its youngest studied end [16,17]. A comparative study specifically in high-level male soccer players, a particularly demanding athletic population, found second-generation ACI associated with meaningfully better outcomes than microfracture at this elite competitive level, reinforcing that the general population-level advantage of ACI over microfracture extends to elite athletic cohorts specifically rather than being diluted at higher performance demands [26].

Longest-term comparative surgical evidence adds a final layer of context: a minimum ten-year randomised comparison of ACI against mosaicplasty, an osteochondral autograft technique, found ACI associated with significantly better clinical outcome at this extended follow-up point, the longest head-to-head randomised comparison available between these two techniques and one that meaningfully informs the

technique-selection discussion this review has developed throughout [21].

Conclusion

Autologous chondrocyte implantation in the athletic knee produces generally high rates of return to sport and demonstrates meaningful long-term durability extending to 10 and, in some series, 20 years post-implantation, with outcome most strongly predicted by patient age, symptom duration, and lesion size and containment rather than surgical technique alone. Comparative evidence against microfracture and osteochondral autograft transfer supports individualised technique selection according to defect characteristics and athlete activity level rather than a single universally preferred approach.

Implications for Sports Medicine Practice

For clinicians counselling athletes considering cartilage repair surgery, three practical points follow from this evidence. First, set return-to-sport and durability expectations according to the specific defect characteristics and patient factors this review has identified as most predictive, rather than a single generic outcome figure [8,14,29]. Second, consider osteochondral autograft transfer as a genuine alternative to ACI for well-selected smaller defects in high-activity athletes, given the comparative evidence this review has summarised [20,22,23]. Third, discuss complication and revision risk explicitly as part of informed consent, since these are non-trivial though generally lower than for many alternative techniques [14,15].

Author Contributions

Odegaardsen S conceived the review question, screened and synthesised the source literature, and drafted the manuscript. Radulescu-Iancu T contributed the imaging and structural-outcome literature search strategy and critically revised the manuscript for radiological content. Steenbrugge J verified the extracted return-to-sport and rehabilitation figures against the cited primary sources and revised the manuscript for important rehabilitation-related content. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this review.

Funding

This review received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Data Availability Statement

No new data were generated or analysed for this review. All percentages and effect estimates reported here are drawn directly from the cited published sources, each of which makes its own underlying data available according to its own journal's policy.

Acknowledgments

The authors thank the investigators behind the autologous chondrocyte implantation and comparative cartilage-repair-technique literature synthesised in this review, whose sustained work made a synthesis of this kind possible.

References

1. Brittberg M, Lindahl A, Nilsson A, Ohlsson C, Isaksson O, Peterson L. "Treatment of deep cartilage defects in the knee with autologous chondrocyte transplantation". *N Engl J Med* 331(1994):889-895.
2. Peterson L, Minas T, Brittberg M, Nilsson A, Sjogren-Jansson E, Lindahl A. "Two- to 9-year outcome after autologous chondrocyte transplantation of the knee". *Clin Orthop Relat Res* 374(2000):212-234.
3. Peterson L, Vasiliadis HS, Brittberg M, Lindahl A. "Autologous chondrocyte implantation: a long-term follow-up". *Am J Sports Med* 38(2010):1117-1124.
4. Minas T, Von Keudell A, Bryant T, Gomoll AH. "The John Insall Award: A minimum 10-year outcome study of autologous chondrocyte implantation". *Clin Orthop Relat Res* 472(2014):41-51.
5. Mithoefer K, Hambly K, Logerstedt D, Ricci M, Silvers H, Della Villa S. "Current concepts for rehabilitation and return to sport after knee articular cartilage repair in the athlete". *J Orthop Sports Phys Ther* 42(2012):254-273.
6. Mithoefer K, Peterson L, Mandelbaum BR, Minas T. "Articular cartilage repair in soccer players with autologous chondrocyte transplantation: functional outcome and return to competition". *Am J Sports Med* 33(2005):1639-1646.
7. Mithoefer K, Hambly K, Della Villa S, Silvers H, Mandelbaum BR. "Return to sports participation after articular cartilage repair in the knee: scientific evidence". *Am J Sports Med* 37 Suppl 1(2009):167S-176S.
8. Krishnan SP, Skinner JA, Bartlett W, et al. "Who is the ideal candidate for autologous chondrocyte implantation?" *J Bone Joint Surg Br* 88(2006):61-64.
9. Kreuz PC, Steinwachs M, Erggelet C, et al. "Results after microfracture of full-thickness chondral defects in different compartments in the knee". *Osteoarthritis Cartilage* 14(2006):1119-1125.
10. Knutsen G, Drogset JO, Engebretsen L, et al. "A randomized trial comparing autologous chondrocyte implantation with microfracture: findings at five years". *J Bone Joint Surg Am* 89(2007):2105-2112.
11. Vasiliadis HS, Wasiak J. "Autologous chondrocyte implantation for full thickness articular cartilage defects of the knee". *Cochrane Database Syst Rev* 10(2010):CD003323.
12. Vanlauwe J, Saris DB, Victor J, et al. "Five-year outcome of characterized chondrocyte implantation versus microfracture for symptomatic cartilage defects of the knee". *Am J Sports Med* 39(2011):2566-2574.

13. Saris DB, Vanlauwe J, Victor J, et al. "Characterized chondrocyte implantation results in better structural repair when treating symptomatic cartilage defects of the knee in a randomized controlled trial versus microfracture". *Am J Sports Med* 36(2008):235-246.
14. Niemeyer P, Pestka JM, Kreuz PC, et al. "Characteristic complications after autologous chondrocyte implantation for cartilage defects of the knee joint". *Am J Sports Med* 36(2008):2091-2099.
15. Harris JD, Siston RA, Pan X, Flanigan DC. "Autologous chondrocyte implantation: a systematic review". *J Bone Joint Surg Am* 92(2010):2220-2233.
16. Filardo G, Kon E, Andriolo L, Di Martino A, Zaffagnini S, Marcacci M. "Treatment of 'patellofemoral' cartilage lesions with matrix-assisted autologous chondrocyte transplantation: a comparison of patellar and trochlear lesions". *Am J Sports Med* 42(2014):626-634.
17. Cvetanovich GL, Riboh JC, Tilton AK, Cole BJ. "Autologous Chondrocyte Implantation Improves Knee-Specific Functional Outcomes and Health-Related Quality of Life in Adolescent Patients". *Am J Sports Med* 45(2017):70-76.
18. Riboh JC, Cvetanovich GL, Cole BJ, Yanke AB. "Comparative efficacy of cartilage repair procedures in the knee: a network meta-analysis". *Knee Surg Sports Traumatol Arthrosc* 25(2017):3786-3799.
19. Ogura T, Mosier BA, Bryant T, Minas T. "A 20-Year Follow-up After First-Generation Autologous Chondrocyte Implantation". *Am J Sports Med* 45(2017):2751-2761.
20. Pareek A, Reardon PJ, Macalena JA, et al. "Osteochondral Autograft Transfer Versus Microfracture in the Knee: A Meta-Analysis of Prospective Comparative Studies at Midterm Follow-up". *Arthroscopy* 32(2016):2118-2130.
21. Bentley G, Biant LC, Vijayan S, Macmull S, Skinner JA, Carrington RW. "Minimum ten-year results of a prospective randomised study of autologous chondrocyte implantation versus mosaicplasty for symptomatic articular cartilage lesions of the knee". *J Bone Joint Surg Br* 94(2012):504-509.
22. Gudas R, Kalesinskas RJ, Kimtys V, et al. "A prospective randomized clinical study of mosaic osteochondral autologous transplantation versus microfracture for the treatment of articular cartilage defects in the knee joint in young athletes". *Arthroscopy* 21(2005):1066-1075.
23. Krych AJ, Harnly HW, Rodeo SA, Williams RJ. "Activity levels are higher after osteochondral autograft transfer mosaicplasty than after microfracture for articular cartilage defects of the knee: a retrospective comparative study". *J Bone Joint Surg Am* 94(2012):971-978.
24. Della Villa S, Kon E, Filardo G, et al. "Does intensive rehabilitation permit early return to sport without compromising the clinical outcome after arthroscopic autologous chondrocyte implantation in highly competitive athletes?" *Am J Sports Med* 38(2010):68-77.
25. Ebert JR, Fallon M, Zheng MH, Wood DJ, Ackland TR. "A randomized trial comparing accelerated and traditional approaches to rehabilitation following matrix-induced autologous chondrocyte implantation". *Am J Sports Med* 36(2008):1246-1257.
26. Kon E, Filardo G, Berruto M, et al. "Articular cartilage treatment in high-level male soccer players: a prospective comparative study of arthroscopic second-generation autologous chondrocyte implantation versus microfracture". *Am J Sports Med* 39(2011):2549-2557.
27. Nawaz SZ, Bentley G, Briggs TW, et al. "Autologous chondrocyte implantation in the knee: mid-term to long-term results". *J Bone Joint Surg Am* 96(2014):824-830.
28. DiBartola AC, Everhart JS, Magnussen RA, et al. "Correlation between histological outcome and surgical cartilage repair technique in the knee: a meta-analysis". *Knee* 23(2016):344-349.
29. Andriolo L, Merli G, Filardo G, Marcacci M, Kon E. "Failure of autologous chondrocyte implantation". *Am J Sports Med* 45(2017):2116-2123.
30. Zaslav K, Cole B, Brewster R, et al. "A prospective study of autologous chondrocyte implantation in patients with failed prior treatment for articular cartilage defect of the knee: results of the Study of the Treatment of Articular Repair (STAR) clinical trial". *Am J Sports Med* 37(2009):42-55.

Cite this article: Odegardsen S, Radulescu-Iancu T, Steenbrugge J. Autologous Chondrocyte Implantation in the Athletic Knee: A Review of Return-to-Play Outcomes and Their Durability. *J Sports Med Pain Manag*. 2026; 7: 007-012.

Ethics Approval and Consent to Participate

Not applicable. This article is a narrative review synthesising previously published, publicly available literature and did not involve the collection of new data from human participants.

Search Strategy

Sources were identified through targeted searches of MEDLINE, Embase, and the Cochrane Library, combined with manual forward and backward citation tracking from the foundational ACI outcome literature, the comparative cartilage-repair-technique literature, and the athlete-specific return-to-sport literature, restricted to peer-reviewed studies reported in English.