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Articular Cartilage Treatment in High-Level Male Soccer Players

A Prospective Comparative Study of Arthroscopic Second-Generation Autologous Chondrocyte Implantation Versus Microfracture

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Investigation performed at the Rizzoli Orthopaedic Institute, Bologna, Italy; the Gaetano Pini Orthopaedic Institute, Milano, Italy; the Fondazione IRCCS Policlinico San Matteo, Pavia, Italy; and the Isokinetic FIFA Medical Centre of Excellence, Bologna, Italy

Background: Soccer is a highly demanding sport for the knee joint, and chondral injuries can cause disabling symptoms that may jeopardize an athlete's career. Articular cartilage lesions are difficult to treat, and the increased mechanical stress produced by this sport makes their management even more complex.

Hypothesis: To evaluate whether the regenerative cell-based approach allows these highly demanding athletes a better functional recovery compared with the bone marrow stimulation approach.

Study Design: Cohort study; Level of evidence, 2.

Methods: Forty-one professional or semiprofessional male soccer players were treated from 2000 to 2006 and evaluated prospectively at 2 years and at a final 7.5-year mean follow-up (minimum, 4 years). Twenty-one patients were treated with arthroscopic second-generation autologous chondrocyte implantation (Hyalograft C) and 20 with the microfracture technique. The clinical outcome of all patients was analyzed using the cartilage standard International Cartilage Repair Society (ICRS) evaluation package. The sport activity level was evaluated with the Tegner score, and the recovery time was also recorded.

Results: A significant improvement in all clinical scores from preoperative to final follow-up was found in both groups. The percentage of patients who returned to competition was similar: 80% in the microfracture group and 86% in the Hyalograft C group. Patients treated with microfracture needed a median of 8 months before playing their first official soccer game, whereas the Hyalograft C group required a median time of 12.5 months ($P = .009$). The International Knee Documentation Committee (IKDC) subjective score showed similar results at 2 years' follow-up but significantly better results in the Hyalograft C group at the final evaluation ($P = .005$). In fact, in the microfracture group, results decreased over time (from 86.8 ± 9.7 to 79.0 ± 11.6 , $P < .0005$), whereas the Hyalograft C group presented a more durable outcome with stable results (90.5 ± 12.8 at 2 years and 91.0 ± 13.9 at the final follow-up).

Conclusion: Despite similar success in returning to competitive sport, microfracture allows a faster recovery but present a clinical deterioration over time, whereas arthroscopic second-generation autologous chondrocyte implantation delays the return of high-level male soccer players to competition but can offer more durable clinical results.

Keywords: cartilage lesion; arthroscopic second-generation autologous chondrocyte implantation; microfracture; arthroscopy; knee; soccer

Soccer is a highly demanding activity, especially in top athletes. High-impact repetitive loading, torsional forces, rapid deceleration motion, as well as frequent pivoting and player contacts explain the high injury level that has

been reported to lead up to 47% of the soccer players retiring because of an injury, mainly in the knee.⁸ In particular, the significant mechanical stress on the articular surface may lead to cartilage damage, which is a major cause of disability in the soccer population. Cartilage lesions are reported at all levels: collegiate, professional, or world-class athletes are most often affected.²⁶ Chondral injuries involve disabling symptoms that may jeopardize an athlete's career; even after suspending playing, surgical

treatment, and long rehabilitation, return to competition is not always achieved.^{28,41} Moreover, injuries to knee cartilage are a risk factor for more extensive joint damage: none of the inflammatory processes are available for its repair, and chondrocytes cannot migrate to the site of injury from an intact healthy site, unlike most tissues.^{5,6,15,32} The development of early osteoarthritis has been reported, especially at the elite level, with a 5-fold increased prevalence of osteoarthritis with respect to the general population.^{8,11,25,28} Soccer is the most commonly played sport in the world, with an estimated 265 million active players and a growing population of athletes, and the detrimental short- and long-term effects of cartilage lesions may have a high social cost.¹

Articular cartilage lesions, with their limited healing potential, are a challenging problem for orthopaedic surgeons, and the high mechanical stress of the articular surface, due to this sport activity, makes their management even more complex. Various techniques have been studied and applied through the years for the treatment of cartilage lesions, from the classic bone marrow stimulation procedures to the more ambitious and modern regenerative techniques.^{20,22,29,33,40} Whereas reparative treatments are mostly aimed at the recruitment of bone marrow cells to obtain potential cartilage precursors and allow a fibrous-cartilaginous tissue to form that lacks the biomechanical and viscoelastic characteristics of normal hyaline cartilage,³¹ the objective of the new bioengineered approach is to produce a hyaline-like tissue and restore a biologically and biomechanically valid articular surface.^{38,39} However, despite thousands of patients treated and several studies suggesting good clinical results and durability of the cell-based procedures, currently, there is no agreement about the effective superiority of the regenerative approach over the others, and both indications and results are still controversial.^{18,19}

The ultimate goal of cartilage reconstruction is to restore the articular surface with a high-quality tissue, thus allowing a return to the original preinjury level of function. In competitive athletes, the time taken to recover is also of primary importance.

The purpose of our study was therefore to evaluate whether the hyaline-like tissue obtained with the regenerative cell-based approach gives these highly demanding athletes a better functional recovery with respect to the outcome offered by the bone marrow stimulation approach. We analyzed the results obtained in high-level soccer players affected by knee cartilage lesions and treated with arthroscopic second-generation autologous chondrocyte implantation (ACI) or the microfracture technique at a mean of 7.5 years' follow-up, and we compared time taken to recover, return to previous activity level, and functional outcome at short- and medium-term follow-up.

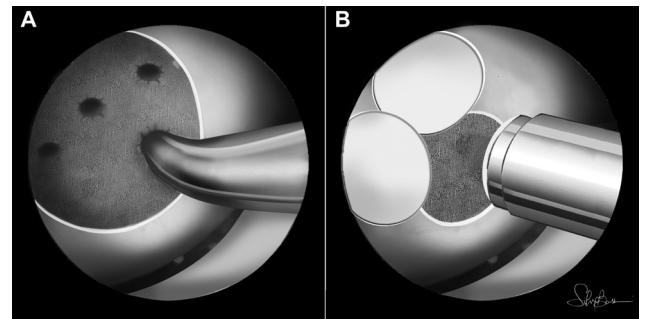


Figure 1. Schematic representation of the surgical treatment: (A) microfracture, (B) arthroscopic Hyalograf C implantation.

MATERIALS AND METHODS

Patient Selection

Three orthopaedic centers participated in this study and were approved by the local ethics committee. Experienced knee surgeons enrolled and treated patients according to the selection criteria. All patients who gave their consent to participate were included in the study. Forty-one high-level male soccer players (professional or semiprofessional) were treated from 2000 and 2006 and prospectively evaluated for a minimum of 4 years (mean \pm SD, 7.5 ± 1.7 years). Twenty-one patients were treated with arthroscopic second-generation ACI and 20 with the microfracture technique (Figure 1). Every center performed only 1 treatment, and so the patient treatment allocation was according to the center the patients went to (all the second-generation ACI treatments were performed at 1 center, whereas 2 groups of 7 and 13 patients, respectively, received microfracture in the other 2 centers).

The study included male athletes complaining of clinical symptoms, such as knee pain or swelling with grade III to IV chondral lesions of the femoral condyles or trochlea greater than 1 cm^2 , as assessed by arthroscopic evaluation. The exclusion criteria included patella or tibial plateau chondral lesions, diffuse arthritis or bipolar ("kissing") lesions, untreated tibiofemoral or patellofemoral misalignment, and knee instability. The patients who presented with anterior cruciate ligament (ACL) lesions underwent a combined surgical procedure of ACL reconstruction during the same surgical session with cartilage harvesting or microfracture. The 2 groups of patients were homogeneous for age, defect size, location, previous and combined surgery, and follow-up, as reported in detail in Table 1.

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TABLE 1
Comparison of the Characteristics of the 2 Groups of Soccer Players Treated With Microfracture Technique and Second-Generation Autologous Chondrocyte Implantation (ACI), Respectively^a

	Microfracture	Hyalograft C	Significance
Athletes, n	20	21	
Level	Tegner 10: 5 Tegner 9: 15	Tegner 10: 6 Tegner 9: 15	NS
Age, mean \pm SD (range), y	26.5 \pm 4.5 (18-35)	23.7 \pm 5.7 (16-37)	NS
Final follow-up, mean \pm SD (range), mo	89 \pm 25 (48-132)	94 \pm 14 (60-120)	NS
Defect size, mean \pm SD, cm ²	1.9 \pm 0.6	2.1 \pm 0.5	NS
Associated surgery	10 (50%) (4 ACL, 1 MCL, 1 tibial osteotomy, 1 loose body removal, 1 calcification removal, 3 meniscectomy, 2 patellar debridement)	12 (57%) (10 ACL, 10 meniscectomy, 2 meniscal suture, 1 loose body removal)	NS
Previous surgery	6 (30%) (7 meniscectomy, 1 shaving, 1 ACL, 1 MCL)	8 (38%) (2 meniscectomy, 2 ACL, 2 microfracture, 1 debridement, 2 loose body removal, 2 shaving, 1 mosaicplasty, 1 patellar realignment)	NS
Location	12 MFC (60%) 4 LFC (20%) 3 trochlea (15%) 1 MFC, LFC (5%)	13 MFC (62%) 4 LFC (19%) 2 trochlea (9%) 1 MFC, trochlea (5%) 1 LFC, trochlea (5%)	NS

^aStatistical analysis shows the homogeneity of the 2 groups. ACL, anterior cruciate ligament; MCL, medial collateral ligament; MFC, medial femoral condyle; LFC, lateral femoral condyle; NS, not significant.

ACI With Hyalograft C

The procedure consisted of 2 arthroscopic surgical steps. The first step involved taking a 150- to 200-mg healthy cartilage biopsy specimen from a nonweightbearing site of the articular surface (intercondylar notch) for autologous chondrocyte cell culture and subsequent seeding onto the hyaluronic acid-based scaffold Hyaff 11 (Fidia Advanced Biopolymers, Padova, Italy). The second step consisted of implanting the bioengineered tissue Hyalograft C (Fidia Advanced Biopolymers) according to the surgical technique described by Macciaci et al.²⁷ A variable diameter delivery device with a sharp edge was used to evaluate the size of the defect. A circular area with regular margins for graft implantation was prepared with a specially designed cannulated low profile drill. The delivery device was then filled with a hyaluronic acid patch, which was transported and placed in the prepared area. The graft was pushed out of the delivery device and positioned precisely within the defect, where it remained tightly fixed to the subchondral bone. Under arthroscopic control, the stability of implanted stamps was evaluated also during cyclic bending of the knee. Dislodgement of the implanted patch was not observed in our series.

Microfracture Technique

Surgery was performed according to the technique described by Steadman et al.⁴² After the surgeon identified

the chondral lesion, the unstable cartilage was removed including cartilage loosely attached to the surrounding rim using a shaver and/or a hand-held angled curette. When present, the calcified layer of cartilage was also removed. Then, multiple holes were made using a Steadman arthroscopic pin. The holes were placed perpendicular to the joint surface approximately 3 to 4 mm apart and about 2 to 4 mm deep, with care taken not to damage the subchondral plate between the holes. Once the holes were completed, the irrigation fluid pump pressure was lowered to visualize the release of fat droplets and blood from the microfracture holes into the knee.

Rehabilitation Protocol

The same step-based rehabilitation approach was used for both treatment groups. The rehabilitation protocol included 4 stages. The transition from one stage to the next was allowed when specific goals were reached concerning functional recovery and clinical outcome.

In the early stage (0-6 weeks), the rehabilitation strategies focused on controlling pain, effusion, loss of motion, and muscle atrophy, and the main goal of the treatment was to protect the initial healing phases by preventing weightbearing for about 4 weeks. Management of post-operative pain allowed for early mobilization, which contributed to faster resolution of swelling, promoted defect healing and joint nutrition, and prevented the development

of adhesions. On the second postoperative day, self-assisted mobilization of the knee or continued passive motion 6 hours daily with 1 cycle per minute was recommended until 90° of flexion was attained. Controlled mobilization exercises with reduced range of motion (ROM), early isometric and isotonic exercises, and controlled mechanical compression were performed. By the third or fourth week, weight touchdown with crutches was allowed and was usually completed within 6 to 8 weeks after surgery. Gait training in a swimming pool facilitated the recovery of normal gait.

The transition to the second stage was allowed after swelling had resolved and when full knee extension, at least 120° of knee flexion, and a correct gait cycle with full weightbearing were achieved. The main goal of the second stage was to return to a normal running mode. The strategy of this stage focused on strengthening exercises in the open and closed kinetic chain, selecting a pain-free ROM, proprioceptive exercises, and aerobic training. Treadmill running was allowed and increased according to the clinical progress. Criteria for progression to the next stage were no pain or swelling after 8 to 10 km/h of running for 15 minutes, good strength recovery compared with the contralateral limb evaluated by clinical examination, and single-legged hop test <20% compared with the contralateral limb.

The main goal of the third stage was to recover sport-specific skills. The strategy focused on eccentric strengthening exercises, advanced proprioceptive exercises, and a sport-specific reconditioning program. When there was no pain or effusion during sport-specific drills and a complete endurance recovery, the final goal was to reintroduce the athlete to competition (phase 4), with specific exercises and drills performed on a playing field first, and then strength exercises for muscular groups of both the injured and the noninjured limbs and stretching of the posterior muscle chain of the lower limbs to maintain physical fitness and prevent the risk of reinjuries.

Follow-up Evaluation

All 41 patients were evaluated preoperatively, at 2 years, and at a final 7.5-year mean follow-up. The clinical outcome of all patients was analyzed using the cartilage standard evaluation form as proposed by the International Cartilage Repair Society (ICRS).¹⁷ A functional knee test was performed according to the International Knee Documentation Committee (IKDC) knee examination form. The lowest ratings in effusion, passive motion deficit, and ligament examination were used to determine the final functional status of the knee (normal, nearly normal, abnormal, or severely abnormal).¹⁷ Patients were asked to evaluate their functional level using the EQ-VAS score.¹⁷ Returning to sports was evaluated with the Tegner score relatively to preoperative and preinjury levels,⁴³ and time to recover was also recorded. The operation was deemed to have failed if the patient needed to repeat surgery because of symptoms due to primary defects. For failed patients, the last clinical evaluation before repeat surgery was considered.

Statistical Methods

All continuous data were expressed in terms of the mean and the standard deviation of the mean. One-way analysis of variance was performed to assess differences among groups when the Levene test for homogeneity of variances was not significant ($P < .05$); otherwise, the Mann-Whitney test was used. The general linear model for repeated measures with the Bonferroni correction for multiple comparisons was performed to test differences of the scores at different follow-up times. The influence of grouping variables on scores at different follow-up times was investigated by the general linear model for repeated measures, with the grouping variable as a fixed effect. The Pearson nonparametric χ^2 test (contingency tables with more than 2 groups) and Fisher nonparametric exact test (contingency tables with 2 groups) were performed to investigate the relationships between grouping variables. The Pearson correlation was used to assess the correlation between continuous variables. The Friedman test was used to test differences among different follow-up times of the objective IKDC. The life table survival analysis with the Wilcoxon-Gehan statistic was used to compare cumulative rates of returning to competitive sports in the 2 groups. For all tests, $P < .05$ was considered significant. Statistical analysis was carried out using the Statistical Package for the Social Sciences (SPSS 15.0, SPSS Inc, an IBM company, Armonk, New York).

RESULTS

No severe adverse events were observed during the treatment and follow-up periods. Both groups showed a statistically significant improvement of all clinical scores from preoperative to final follow-up.

Group of Patients Treated With Microfracture

There was a significant improvement in the IKDC subjective score from preoperative (47.3 ± 8.5) to 2 years' follow-up (86.8 ± 9.7) ($P < .0005$), followed by a significant deterioration of the results at the final follow-up (79.0 ± 11.6) ($P < .0005$) compared with the previous evaluation at 2 years (Figure 2). The IKDC objective score increased significantly from 5% normal and nearly normal knees before the operation to 90% at 2 years' follow-up ($P < .0005$); then, results remained stable with 90% normal and nearly normal knees at the final follow-up evaluation (Table 2). The EQ-VAS score increased from 70.0 ± 14.7 to 81.8 ± 15.0 at 2 years ($P = .07$) and to 84.0 ± 10.8 at the final follow-up ($P = .001$) (Figure 3). The Tegner score showed a significant improvement from preoperative level (4.7 ± 1.6) to 2 years (8.5 ± 1.6) ($P < .0005$) and final follow-up (6.9 ± 1.8) ($P = .003$) (Figure 4). Patients returned to preinjury activity level (9.2 ± 0.4) at 2 years; however, a decrease in sport activity from 2 years to final follow-up was found ($P = .001$).

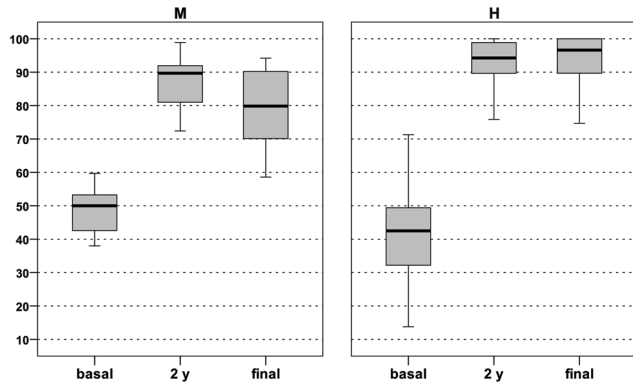


Figure 2. International Knee Documentation Committee (IKDC) subjective score: improvement from the preoperative level to 2 years and final follow-up. Better results were found in the Hyalograft C group (H) than for the microfracture group (M) at the final evaluation.

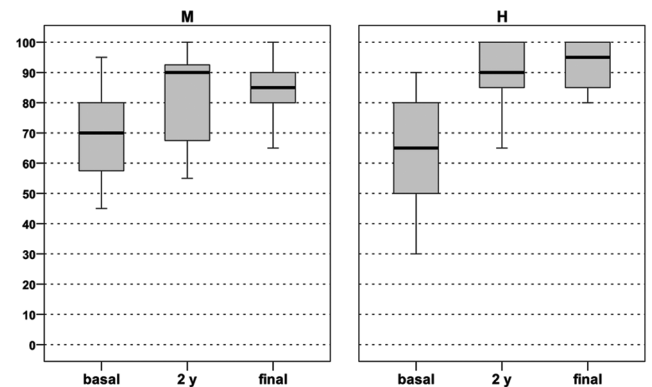


Figure 3. The EQ-VAS score: improvement from the preoperative level to 2 years and final follow-up. Better results were found in the Hyalograft C group at the final evaluation.

TABLE 2

Objective International Knee Documentation Committee (IKDC) Score: Improvement From the Preoperative Level to 2 Years' and Final Follow-up in the 2 Treatment Groups

		Time	A	B	C	D
Microfracture	Basal		0	1	14	5
	2-year follow-up		13	5	2	0
	Final follow-up		13	5	2	0
Hyalograft C	Basal		2	4	9	6
	2-year follow-up		16	4	1	0
	Final follow-up		15	5	1	0

Group of Patients Treated With Hyalograft C

There was a significant improvement in the IKDC subjective score from preoperative (43.2 ± 13.7) to 2 years' follow-up (90.5 ± 12.8) ($P < .0005$); then, results remained stable until the final follow-up evaluation (91.0 ± 13.9) ($P < .0005$) (Figure 2). The IKDC objective score increased significantly from 19% normal and nearly normal knees before the operation to 95% at 2 years' follow-up ($P < .0005$); then, results remained stable with 95% normal and nearly normal knees at the final follow-up evaluation (Table 2). The EQ-VAS score increased from 64.1 ± 17.2 to 90.5 ± 9.3 at 2 years ($P < .0005$) and 91.2 ± 10.2 at the final follow-up ($P = .0005$) (Figure 3). The Tegner score showed a significant improvement from preoperative level (3.5 ± 1.3) to 2 years (8.0 ± 2.1) ($P < .0005$) and final follow-up (7.8 ± 1.6) ($P < .0005$) (Figure 4). Patients returned to preinjury activity level (9.3 ± 0.5) at 2 years. One case that failed at 6 years was treated with microfracture and medial meniscal allograft.

When comparing the 2 groups, similar results were found in returning to sports. In the microfracture group, 80% of the patients returned to competition, with 75% at

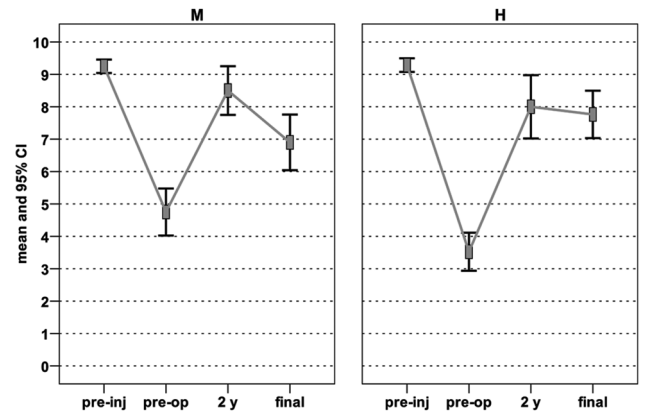


Figure 4. Tegner score: improvement from the preoperative level to 2 years and final follow-up.

their previous level. In the Hyalograft C group, 86% of the patients returned to playing soccer at the competitive level, with 67% at their previous level. There was no difference in the length of time played at the same level after recovery: 3.5 ± 2.4 years in the microfracture group and 3.0 ± 2.9 years in the Hyalograft C group. However, a marked difference was found in the time needed to return to training with the team, with a median of 6.5 months in the microfracture group versus 10.2 months in the Hyalograft C group ($P = .01$) (Figure 5), and to return to competitive sport activity level: patients treated with microfracture needed a median of 8 months before their first official soccer game, whereas patients in the Hyalograft C group required a median time of 12.5 months before playing their first official game ($P = .009$) (Figure 6).

No differences were found in the IKDC objective score and sport activity level achieved at 2 years and final follow-up. However, whereas similar results were achieved at 2 years' follow-up according to the IKDC subjective score, better results were obtained in the Hyalograft C group at the final evaluation ($P = .005$). The EQ-VAS score

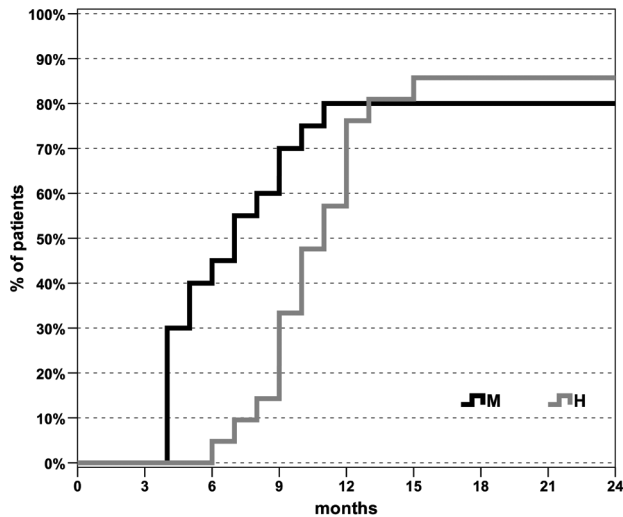


Figure 5. The curves show the time needed to return to training with the team in the microfracture and Hyalograf C group, respectively.

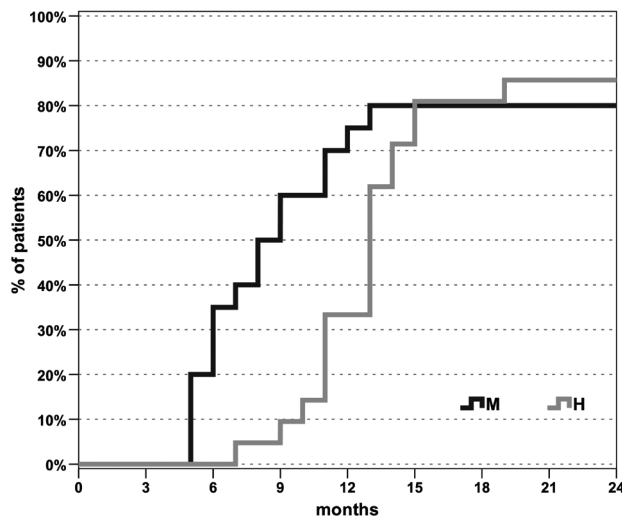


Figure 6. The curves show the time needed to return to competitive sport activity level (first official soccer game) in the microfracture and Hyalograf C group, respectively.

gave better results in the Hyalograf C group at the final evaluation ($P = .035$).

DISCUSSION

The study of the treatment of cartilage injuries in soccer players is of marked interest. In fact, several studies have shown the positive influence of exercise after surgical treatment of articular cartilage defects and that physical training and an active lifestyle improve long-term results after ACI^{7,24,28,36}; on the other hand, restoring the

articular surface in knees under high-level stress is particularly challenging.

Among the numerous treatment options proposed for cartilage lesions, there are 2 main categories: the reparative and the regenerative procedures. Bone marrow stimulation techniques such as microfracture have been developed to favor stem-cell migration from the marrow cavity to the fibrin clot of the defect⁴¹; however, they produce a predominantly fibrous repair tissue, with mostly type I collagen fibrocytes and an unorganized matrix,³¹ and seem to offer good short-term clinical outcome but fail to provide long-lasting results.^{21,29,40} Conversely, the modern regenerative techniques aim to produce a hyaline-like tissue and therefore achieve good and durable clinical results. First-generation ACI, proposed by Brittberg et al in 1994,³ involves the reimplantation of autologous cells isolated from cartilage harvested from the patient and expanded in vitro. Since the introduction 2 decades ago of the cell-based approach, both the production of a hyaline-like articular surface and a satisfactory clinical outcome have been reported.^{4,33} Using this procedure, Mithoefer et al²⁹ reported that 83% of top soccer players returned to their previous level of sport after a mean recovery period of 14 months, 87% of whom maintained their ability to play soccer at 52 months postoperatively.

The development of tissue bioengineering led to second-generation ACI: the use of a 3-dimensional matrix for chondrocyte transplantation offered similar results while overcoming most of the biological and surgical concerns related to the first-generation procedures.^{20,22,27} Despite some dispute about the effective superiority of one procedure over the others,^{18,19} good results have been widely reported for different types of scaffold,^{2,12,14,23,30} and the higher quality of the repair tissue obtained with the regenerative techniques seems to allow a better long-term outcome particularly in the young, active population.^{7,21} Bioengineered tissues significantly reduce the inherent fragility of ACI grafts during the early postoperative stage and accelerate patient recovery. In a randomized controlled study, Ebert et al⁹ compared traditional with accelerated approaches to postoperative rehabilitation after second-generation ACI and showed the possibility to speed up the recovery of normal gait function while reducing knee pain and graft-related complications. Moreover, the easy handling of the scaffolds even allowed the development of arthroscopic implantation techniques,^{10,13,27,37} resulting in lower surgical trauma and mechanoreceptor disruption. The reduction in surgical morbidity had a marked impact on rehabilitation, thus enabling a further acceleration in function recovery.¹²

In a group of 31 competitive athletes who underwent arthroscopic second-generation ACI, it was observed that intensive rehabilitation, if properly performed, did not jeopardize graft vitality but optimized the results, with a better clinical outcome over time and a shorter recovery time: 80.6% of the athletes treated with Hyalograf C returned to their previous activity level in 1 year. It was thought that a more strict and intensive rehabilitation

program might even further shorten the time needed to return to competition.⁷

Also in the present study, a step-based rehabilitation protocol (rather than a more rigid time-based strategy) was applied in both procedures, thus allowing a fast and safe recovery of full function. However, although adequate mechanical stimulation can favor and speed up the remodeling process, presently, there is no established and tested graft maturation timeline, and the bioengineered graft still needs to be protected from inappropriate loading and excessively premature high-impact activities that are therefore delayed for precautionary reasons to limit the risk of graft failure.^{16,35} This explains the faster return to previous activity level observed in our study in the microfracture group. Soccer players treated with microfracture returned to competition 4.5 months earlier than patients who underwent Hyalograft C implantation, thus confirming the short recovery time reported by Riyami and Rolf³⁴ in professional soccer and rugby players treated with microfracture, 83% of whom resumed full training between 5 to 7 months after treatment.

Further evaluation of our results showed that, despite the slower recovery in the Hyalograft C group, the 2 different treatment approaches offer a similar success rate in returning to previous sport activity. The evaluation of the clinical outcome at 2 years' follow-up showed similar results for the 2 treatments, according to findings already reported in the literature: Knutsen et al^{18,19} did not report any differences between ACI and microfracture at 2 and 5 years' follow-up. However, they also reported that ACI biopsy specimens tended to have a more hyaline-like appearance and that none of the failures after microfracture presented high-quality repair cartilage, thus suggesting that an inferior-quality repair tissue might increase the risk of failure or present a poorer outcome over time.

Saris et al^{38,39} supported this hypothesis. Whereas comparable clinical outcome was found between microfracture and characterized chondrocyte implantation (CCI) at short-term follow-up despite the superior histomorphometric and histological score observed in the CCI group, the quality of the repair tissue significantly influenced the later follow-up. Marrow stimulation procedures lead to the formation of a fibrous tissue that cannot ensure good results over time; conversely, ACI procedures may regenerate a hyaline-like tissue that undergoes a remodeling process, thus leading to superior clinical results detectable only after at least 3 to 4 years' follow-up.^{21,30,31,38,39}

Good stable results were also reported²¹ in 40 patients treated with Hyalograft C at 5 years' follow-up compared with microfracture, where a deterioration was observed over time. The present study confirms, in a highly demanding population of athletes, a better functional recovery with respect to the outcome offered by the bone marrow stimulation approach at medium- to long-term follow-up.

The main weakness of our study is that it is not a randomized clinical trial. The treatment allocation according to the center the patients attended is a bias, but this could be considered a sort of "geographic randomization," and experienced surgeons performed the operations according

to the hospital policy, using always the same technique for the treatment of cartilage lesions in soccer players. Another limitation is the presence of a similar level of previous and associated surgeries but with a different percentage of operation type in the 2 groups. Moreover, there is a lack of imaging and histological comparison. However, return to competition is the most important outcome for this specific population of high-level athletes, and clinical outcome, time needed to return to official games, and time played after recovery are reliable outcomes for the success of the procedures. The main advantage of the study is the high number of homogeneous top soccer players included and the relatively long (7.5 years) follow-up, thus giving the opportunity to evaluate the results of cartilage treatments in a joint with high mechanical stress and extreme functional requirements.

Articular cartilage lesions are difficult to treat, in particular in highly demanding patients, and indications and results with the various surgical procedures are still controversial. Our study reports and compares the outcome obtained with 2 of the main surgical approaches used for chondral defects and may help physicians and athletes in choosing the most appropriate strategy for the treatment of cartilage lesions. The fast recovery offered by microfracture has to be balanced with the clinical deterioration at medium-term follow-up, thus making the regenerative approach preferable and suggesting limiting the bone marrow stimulation procedures mainly for athletes in the final years of their career who do not wish to stop playing for a long period or athletes risking contracts and careers. In all cases when it is possible to delay the return to competition for a few months, the regenerative approach should be preferred, as it seemed to yield better clinical results over time.

CONCLUSION

The analysis of high-level soccer players treated with arthroscopic second-generation ACI on hyaluronian-based matrix or microfracture has shown satisfactory clinical outcomes at short-term follow-up for both techniques. However, important differences have been reported between these 2 different surgical procedures. The bone marrow stimulation approach allows a faster recovery but results in a clinical deterioration over time, whereas the regenerative approach delays the return to competition but can offer more durable, good clinical results.

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