MINERVA ORTOP TRAUMATOL 2011;62:297-309

Techniques of cartilage repair in athletes

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Articular cartilage injury in the athlete's knee presents a difficult clinical challenge and has been identified as an important cause of permanent disability because of the high mechanical joint stresses in athletes. Management of chondral defects in the athlete is complex and multi-factorial. Various techniques have been developed to treat this injury and research is still going on to improve the outcome. The techniques vary from intra articular injection of viscosupplements and platelet-rich plasma to more invasive techniques like ACI, OATS, MACI and microfracture. More recently the role of bone marrow derived mesenchymal stem cells is being extensively explored with early good results. Irrespective of the technique used the role of good post operative rehabilitation cannot be over emphasised. There is little high-level evidence to support one procedure over another, although good short-term and midterm outcomes with a fair rate of return to pre-injury level of sports can be achieved with cartilage repair and restoration in the athlete.

Key words: **Athletes - Cartilage - Platelet-rich plasma - Mesenchymal stem cells.**

Articular cartilage lesions of the knee represent a challenging problem, which is being increasingly identified as a source of functionally limiting injuries in athletes, in association with acute ligament, meniscal tears, patellar dislocation and osteochondritis dissecans.[1, 2] Traditionally, attempts at treating these lesions have been palliative in nature and over time patients have subsequently progressed through chondropenia to symptomatic arthritis; this can be even more devastating in high-demand professional athletes, representing a risk factor regarding their return to pre-injury level of participation.[3]

Articular cartilage is a thin layer of specialized connective tissue lining the articulations of diarthrodial joints, characterized by unique properties, which enable an almost frictionless joint movement and protect the underlying bone from excessive load and trauma, by dissipating the forces produced during movement. However, articular cartilage has a limited intrinsic healing potential due the presence of very few specialized cells with a low mitotic activity; furthermore, cartilage is avascular and there is a lack of source of undifferentiated cells that can promote tissue repair.[4] Once injury occurs, cartilage gradually degenerates and predisposes to early osteoarthritis (OA).[5] Therefore it is critical to restore a smooth cartilage surface in order to withstand ex-

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cessive joint mechanical stresses from shear and compressive load from cartilage to bone.

The incidence of chondral defects is frequent with sporting injuries, especially in over 40 years of age patients, leaving often persistent pain. Curl *et al.* reviewed 31516 knee arthroscopies and found that chondral injuries were reported in 63% of the cases.[6] Additionally, in a recent systematic review of 11 studies including 931 athletes, more than half of asymptomatic athletes had a full-thickness cartilage defect.[7] Important factors, which are involved in athletics injuries, are: the mechanism of the injury, speed and direction of the force and size of the playing field, which vary in different sports. In addition to acute cartilage trauma, subchondral bone bruises are present in up to 80% of the ACL injured knees,[8] acting as a cause of persistent pain and progressive cartilage degeneration.[9] The post injury joint environment can thus result in significant loss of articular cartilage in ACL and/or meniscal injured knees due to both mechanical (altered joint surface contact pressures) and biochemical factors. Overuse injuries on the other hand are usually caused by joint instability and malalignment.[10] Repetitive cartilage trauma due to pathologic high rate loading speeds up its destruction. Furthermore high intensity exercise has been shown [9] to decrease cartilage proteoglycans content and cause chondrocyte apoptosis leading to progressive chondropenia.

Through the years various treatment modalities have been used to address these conditions with varying success such as arthroscopic debridement, osteochondral autologous transplantation and microfractures. In addition to repair of cartilage injury, associated pathologies as ligament instability, meniscal absence, patellofemoral mal-tracking and tibio-femoral axis deviation should be treated before or in a concomitant procedure in order to achieve safe return to previous sport activities, long term results and prevent joint from high mechanical stresses and progressive degeneration and early OA.[11]

Recently the trend is going towards preventive interventions and therapeutic solutions that can lead to an enhancement of tissue regeneration and the reduction of degenerative mechanisms. Although advances in preventive and conservative management of articular injuries have been made, orthopedic surgeons can now offer professional athletes a variety of biologic reparative or restorative options to address this pathology and allow successful, prolonged return to play, in what earlier might have been career-ending injuries.

Diagnosis

Diagnosis of articular cartilage injuries in professional athletes is often easier and more accessible due to the resources which teams offer the medical support staff. As compared with the general public, the mechanism of injury is often observed by the team doctor or athletic trainer and can be reviewed on videotape. Symptoms are frequently nonspecific, decreased range of motion with crepitus or popping during the arc of motion, joint line or condylar tenderness to palpation, pain at extremes of motion and variable swelling or effusion. Joint instability may be a contributing causal factor or concurrent injury. Several authors have reported specific symptoms synonymous to chondral defects. Brittberg *et al.* and Ochi *et al.*[12-14] stressed that knee pain, symptoms of locking, retropatellar crepitus, and swelling are among the prominent findings to look out for. Other authors including Hangody *et al.*[15, 16] mentioned that instability could also be present. As signs and symptoms elicited during physical examination can mimic the presentation of other knee pathologies, authors agree that correlation with other diagnostic modalities should be made routinely to increase the accuracy of diagnosis.

Since the founding of International Cartilage Repair Society (ICRS) progress have been made in standardizing the evaluation measurement tools for cartilage injury and repair. A clinical and arthroscopic evalua-

TABLE I.—*ICRS classification.*

Grade	ICRS classification
0	Normal
1	Nearly normal (soft indentation and/or superficial fissures and cracks)
2	Abnormal (lesions extending down to <50% of cartilage depth)
3	Severely Abnormal (cartilage lesions >50% of cartilage depth)
4	Severely abnormal (penetrating subchondral bone)

tion system is now available (Table I) and in the near future, it is expected that a specific imaging (MRI) technique along with other new tools for documenting pre-operative and post-operative status of the normal and repaired cartilage will be recommended.[17]

Imaging

The standard radiographic evaluation should include a standing AP long-leg radiograph, including also hips and ankles, standing AP/lateral views of knees, skyline patellofemoral and standing 45° bend knee views.

Among the diagnostic imaging modalities used, MRI has been developed for the earlier and more quantitative detection of articular cartilage changes, having a sensitivity which is >95%.[18-20] Aside from delineating the extent of the articular cartilage lesions, subchondral bone and associated ligament or meniscal injuries can also be assessed. The use of fast-spin-echo (with or without fat suppression) and/or fat-suppressed (or water-selective excitation) spoiled gradient-echo image for better resolution has been recommended.[21] Signal properties of articular cartilage are dependent on: MR pulse sequence utilized, cellular composition of collagen, proteoglycans and water, orientation of collagen in different laminae of cartilage, and effective cartilage pulse sequencing. MRI techniques such as the delayed Gadolinium-Enhanced MRI of Cartilage (dGEMRIC) and T2 relaxation time mapping have been available recently, in the evaluation of articular cartilage, providing the ability of the glycosaminoglycan content visualization, the measurement of collagen content and the mapping of anatomical zones of cartilage.[22-24]

Non-operative treatment

High-demand professional athletes subject their joints to both direct and indirect forces that can result in articular cartilage and associated injuries. Some of these are sports-specific and may be related to other variables such as playing surface, fatigue from overscheduling, etc.; however, certain general non-operative principles can be followed. Symptomatic treatment of acute injury with ice, non-steroidal anti-inflammatory drugs (NSAIDs) and/or chondroprotective agents (such as glucosamine and chondroitin) can minimize cartilage damage. Many human clinical trials on glucosamine (1500-2000 mg/day), chondroitin sulfate (800-1200 mg/day) and Avocado-Soy Unsaponifiables (300-600 mg/day) have shown positive results either for structure modifying effects or pain/function improvement.[25-28] Importantly, structural benefits were independent of symptom relief.[29-31] Mechanical principles such as protective weight bearing on ambulatory aids, protected range of motion/weight bearing with bracing or cartilage simulation with continuous passive motion are also helpful in acute and sub-acute settings.

Intra-articular injections

CORTICOSTEROIDS

Injectable corticosteroids are used for symptomatic relief for numerous intra-articular problems and have yielded short-term improvement with local or systemic side effects.[32-36] Cortisone joint injections should neither be used in an acute injury (impairing initial natural inflammatory response and potentially delaying healing) nor immediately prior to competition.

Viscosupplementation

Viscosupplement injections (hyaluronic acid, HA) may also be used for short-term care of chondral damaged joints as an alternative to corticosteroids. Viscosupplements have both chondroprotective and anti-inflammatory effects.[37] Chondroprotection occurs through down regulation of the gene expression of osteoarthritis-associated cytokines and enzymes.[38]The anti-inflammatory effect occurs by down regulation of TNF-alpha, IL-8 and iNOS in synoviocytes.[37] Although most of the deleterious side effects associated with cortisone shots are absent, up to 8% of patients receiving intraarticular viscosupplement injections may experience a reversible "pseudoseptic" inflammatory response, potentially knocking the athlete out of several days of productive competition.[39]These chondroprotective effects have driven the use of viscosupplementation in the post-operative knee. Pain that persists after arthroscopy can be decreased with the use of hyaluronic acid injection. It has been shown to result in decreased joint swelling and to be NSAID sparing.[40]

Platelet-rich plasma

Platelet-rich plasma (PRP) can be defined as the volume of the plasma fraction from autologous blood with platelet concentration above baseline (200000 platelets/µL).[41] Platelets contain many important bioactive proteins and growth factors, these factors when secreted regulate key processes involved in tissue repair, including cell proliferation, chemotaxis, migration, cellular differentiation, and extracellular matrix synthesis.[42-44] The rationale for topical use of PRP is to stimulate the natural healing cascade and tissue regeneration by a "supra-physiological" release of platelet-derived factors directly at the site of treatment. Growth factors mediate the biological processes necessary for repair of soft tissues such as muscle, tendon and ligament following acute traumatic, or overuse injury, and animal studies have demonstrated clear benefits in terms of accelerated healing and acting as anti-inflammatory.[45] Many authors have used PRP to treat chondral defects in athletes and obtained good results.[46-48] Kon and Mandelbaum data from a prospective randomized study comparing PRP to HMW HA as well as LMW HA showed superior outcomes with PRP injections.[49] Autologous PRP can be obtained from a simple blood extraction using commercially available kit. Once the blood is collected it should undergo a centrifugation process to produce PRP.

We also prospectively followed up 50 patients with early knee OA (Kellgren-Lawrence classification 1-3). All patients were involved in various sports activities – football (14%), skiing (14%), motocross (12%), basketball-volleyball (12%), jogging (10%) and various others (tennis, bicycling, walking, trekking etc) - but not at professional level. All patients (31 males and 19 females) were treated with 2 intra-articular injections (1 monthly) with autologous PRP (Regen® ACR-C, RegenLab, Switzerland). After extraction of blood, the sample was centrifuged for 9 min at 3100 rpm according to recommendation of the manufacturer. Subsequently we obtained the fraction of PRP and finally we proceeded to the intrarticular infiltration, under sterile aseptic conditions, applying locally topical anesthetic skin refrigerant prior to the injections (Figure 1 A, B). All patients were followed up for a minimum period of 1 year (12-26 months). The mean age of patients was 47.7 years, ranging from 32 to 60 years and the BMI was 26.7 (SD 2.4). Visual Analogue Score (VAS) for pain, International Knee Documentation Committee subjective and objective score (IKDC), Knee Injury and Osteoarthritis Outcome Score (KOOS), Tegner and Marx scores were collected at pre-treatment evaluation and at 3, 6 and 12-month follow up. All patients showed significant improvement in all scores at final follow-up ($P<0.005$) and returned to previous activities including recreational sports. No adverse reactions as infection, swelling, acute pain or any major complication were noted.

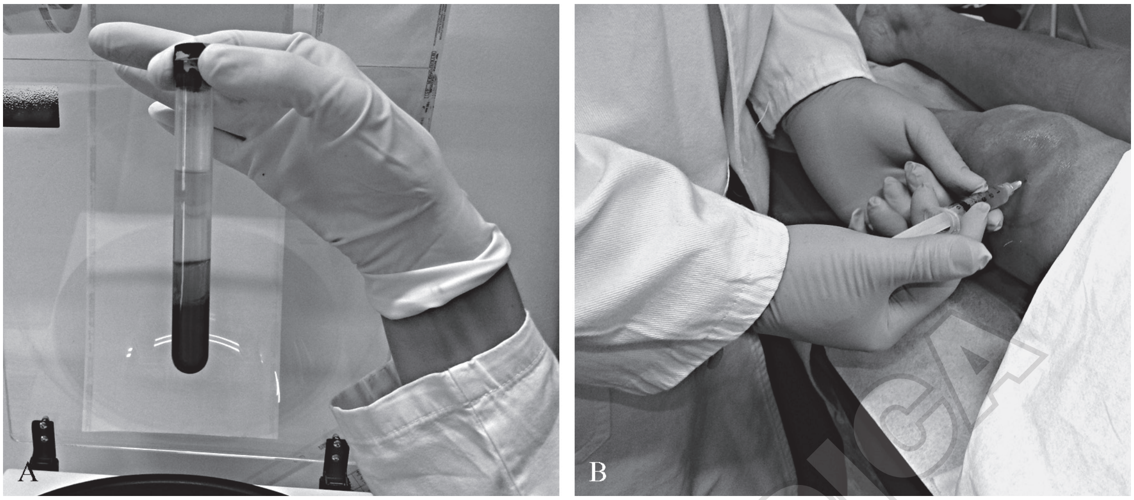

Figure 1.—PRP preparation: A) fraction of PRP after blood centrifugation (yellow upper part in tube); B) knee intrarticular PRP infiltration by a supra-patellar approach.

Although much attention has turned to the use of PRP injections for promotion of soft tissue healing, there is no real convincing scientific consensus till now on the clinical benefits of PRP injection in professional athletes, while there is widely varying composition of the end-product PRP prepared by the different commercially available systems. However effective January 2011, WADA and USADA (International and United States anti-doping agencies) have removed PRP from their prohibited lists, following lack of current evidence concerning the use of these methods for performance enhancement beyond a potential therapeutic effect.[50]

Surgical treatment

Several options exist in the treatment of cartilage lesions: any form of planned treatment should be based on patient characteristics and expectations, clinical symptoms and parameters such as lesion size, depth and associated issues like leg axis alignment, ligament and meniscal integrity and presence of bone deficiencies. Furthermore, other factors related to the patient (e.g. age, genetic predisposition, level of activity and associated pathologies) should not be ignored.

Coexisting pathologies

The coexisting pathologies that need to be addressed for successful reconstruction are tibio-femoral axial alignment, patellofemoral alignment, ligamentous insufficiency, meniscal absence and bone deformities.[11] Knee osteotomies are used to correct varus or valgus malalignment associated with unicompartmental osteoarthritis and can be combined with cartilage repair procedures. Opening wedge high tibial osteotomies are used extensively for the treatment of varus osteoarthritis as distal femur osteotomies are indicated mainly to correct valgus deformities. Correction of the axial deformity should be performed prior to cartilage defects repair, in a concomitant or staged procedure.

When patello-femoral malalignment is present with a trochlear and/or patellar chondral lesion, a thorough evaluation must be carried out primarily in order to restore normal patellar tracking. Patellofemoral tracking correction often requires soft tissue balance through repair, tightening or reconstruction of the medial patellofemoral ligament, or step cut lengthening of the lateral retinaculum, or titrated lateral release. A concomitant tibial tuberosity anteromedialization (AMZ) with Fulkerson's technique [51] is widely used to optimize the environment for the cartilage implant. Rarely a trochleoplasty could be necessary.

Ligamentous insufficiency is a negative factor in chondral graft healing; thus, ACL reconstruction, in a staged or concomitant procedure, must be performed to ensure graft protection and safe return in daily life activities or sports.

Meniscal absence is also an important factor to consider and meniscal transplantation might be necessary;[52] furthermore, cartilage degeneration is associated with higher articular contact stress identified to occur following even partial meniscectomy. In the literature there is little evidence to support if concomitant meniscus transplantation following osteotomy will delay the recurrence of arthritic symptoms; however, restoration of the meniscus it is supposed to be valuable.

Cartilage repair techniques

Traditional palliative techniques or newer reparative treatment options have been utilized to improve cartilage lesions healing and they have demonstrated variable results. Numerous treatment options and proposed algorithms have evolved over the past two decades, which stress on biologic repair of articular cartilage lesions and supplement previous first line techniques, such as arthroscopic debridement or Pridie drilling. These include marrow stimulation techniques (abrasion arthroplasty and microfracture), osteochondral allograft transfers (OATS/mosaicplasty) and both 2-stage 1st and matrix-based 2nd generation autologous chondrocyte implantation (ACI & MACI).

Arthroscopic debridement and cartilage abrasion can provide symptomatic pain relief with no actual hyaline tissue formation. However, these techniques remove superficial cartilage layers, which include collagen fibers that are responsible for the tensile strength, creating a less functional cartilage tissue.[53] However it is often used as a first-line treatment for small cartilage defects in order to remove unstable cartilage flaps.

Bone marrow stimulation techniques, such as subchondral plate drilling or microfracture [54] have been reported to stimulate production of hyaline-like tissue with variable properties and durability compared to normal cartilage decreasing in some cases pain and disability.[55] However recent studies demonstrated that these techniques produce fibrocartilaginous tissue, which degenerates with time.[56-59] Mithoefer *et al.*[60] reported on 32 recreational competitive and professional high-impact, pivoting sports athletes (including 9 football and 14 basketball players) who underwent microfracture repair of single full thickness lesions of the distal femur. Only 25% returned to regular participation in the sports at pre-injury level and outcome scores subsequently decreased in almost 40%. Positive variables for return to play were athlete age less than 40 years old, smaller lesions (<2 cm^2), less than 12 months preoperative symptoms and no previous surgeries. In a review of 28 studies with over 3000 microfractures,[61] patients demonstrated promising short term results; the authors however cautioned against limited hyaline cartilage repair tissue (quality and volume) and functional deterioration after two years.

Osteochondral autologous transplantation (OATS) and mosaicplasty can restore normal cartilage tissue, but they can be applied only to small defects (10-12 mm) and there are some concerns regarding donor site morbidity.[56, 62] Osteochondral allograft transplantation should be suggested in older athletes with defect depths of more than 6 mm to 8 mm.

Autologous chondrocyte implantation (ACI), which was first introduced by Peterson,[63] has been proven to be capable of restoring normal hyaline-like cartilage tissue, which is mechanically and functionally stable even in athletes at long-term follow up. However, this two-step procedure and showed local morbidity for periosteal harvest and uncertain distribution of chondrocytes solution.[19, 20, 64-66] Additionally, the possible complication of periosteal patch hypertrophy prompted the scientific community to develop new techniques including second generation ACI. The use of a three-dimensional scaffold for autologous chondrocyte culture was developed with the aim to improve both the biological performance of chondrogenic autologous cells as well as to renders the surgical technique easier and surgeons have been enabled to perform this procedure arthroscopically.[67-74] Second generation ACI should be suggested in young athletes with large superficial cartilage defects; furthermore it shows favorable results in lesions located at the patellofemoral joint.[75] However this is still a two-step procedure with arthroscopic evaluation and biopsy followed by implantation, either arthroscopically or by mini-arthrotomy.[68, 71, 72, 75, 76]

Since 2001, we have participated in an ongoing observational multicenter investigation to evaluate the long-term clinical outcomes of the treatment with Hyaluronic Acid (HA) scaffold (HYAFF 11® Fidia Advanced Biopolymers, Abano Terme, Italy).[68, 75, 77-79]; 141 patients with follow up assessments ranging from 2 to 5 years (average follow up time: 38 months) were evaluated. At follow up 91.5% of patients improved according to the International Knee Documentation Committee (IKDC) subjective evaluation; 76% and 88% of the patients had no pain and mobility problems respectively assessed by the Euro Qol-EQ5D measure. Furthermore, 95.7% of the patients had their treated knee normal or nearly normal as assessed by the surgeon; cartilage repair was graded arthroscopically as normal or nearly normal in 96.4% of the scored knees; the majority of the second-look biopsies of the grafted site, histologically, were assessed as hyaline-like. A very limited complication rate was recorded in this study.[76]

We also evaluated 32 patellofemoral full-thickness chondral treated with Hyalograft C;[75] the IKDC and EuroQoL EQ-5D scores demonstrated a statistically significant improvement ($P<0.0001$). Objective preoperative data improved from 6/32 (18.8%) with (IKDC) A or B to 29/32 (90.7%) at 24 months after transplantation. Mean subjective scores improved from 43.2 points preoperatively to 73.6 points 24 months after implantation. MRI studies at 24 months revealed 71% to have an almost normal cartilage with positive correlation with clinical outcomes. Second-look arthroscopies in 6 cases revealed the repaired surface to be nearly normal with biopsy samples characterized as hyaline-like in appearance.

In another study, Mithoefer *et al.*[80] have reported over 95% good- excellent results and that 60% of 20 adolescent athletes with full-thickness chondral defects of the distal femur treated with ACI returned to high impact sports at or above their pre-injury level. Concurrent procedures did not affect outcomes. Same authors [81] have reported over 70% good to excellent results in competitive soccer players, with 80% returning to previous skill level and 87% maintaining their ability to play soccer for over four years postoperatively. This study reiterated the importance of shorter periods of preoperative symptomatology (less than 12 months), younger athletes (under 25-year-old) and also concluded that concomitant realignment or stabilizing procedures did not adversely compromise the athletès ability to return to play. Delay in treatment also negatively affected the quality of repair tissue. Minas *et al.*[82] reported a 3-times higher failure rate of larger (>4 cm^2) defects treated by ACI following a previous marrow stimulation technique, suggesting that alteration of the joint's subchondral environment was detrimental to any overlying cartilage repair tissue.

Mesenchymal stem cells

Recent directions in cartilage repair are moving towards the possibility to perform one-step surgery; several groups are analysing the possibility to use mesenchymal stem cells (MSC) with chondrogenic potential and growth factors (GF) avoiding the first surgery for cartilage biopsy and subsequent chondrocyte cell cultivation with a significant reduction of the cost of the total procedure.[83-86] Some surgical techniques have been tested in animals for MSCs implantation including the simple injection of bone marrow aspirate concentrate cells (BMAC) into the lesion, which improved full-thickness cartilage repair compared to microfracture in an equine model of extensive carti-

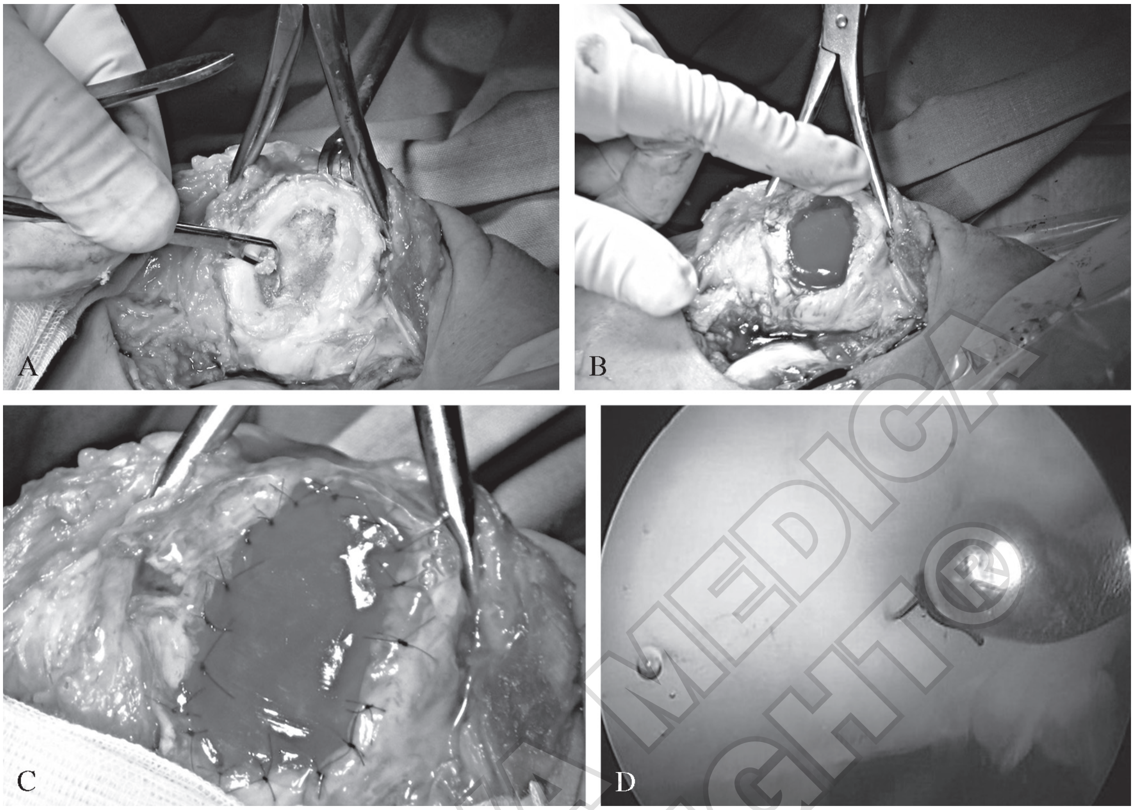

Figure 2.—A) Debridement of a grade IV lesion of the patella; B) BMAC clot after activation is pasted into the prepared lesion; C) patellar lesion covered with a collagen type I/III matrix after pasting BMAC clot; D) second look arthroscopy at 2-year follow-up.

lage loss. MSC have a self-renewal capacity and multi-lineage differentiation potential and they can be characterized by their cultivation behavior and their differentiation potential into adipogenic, osteogenic and chondrogenic cells; therefore, once MSC are cultured in the appropriate microenvironment, they can differentiate to chondrocytes and form cartilage.[87-90, 92] Wakitani *et al.*[91] have used autologous culture expanded BMSC transplantation for repair of cartilage defects in osteoarthritic knees and they concluded that MSC was capable of regenerating a repair tissue for large chondral defects. Giannini *et al.*[93] presented their one-step surgery procedure using MSC and scaffold in cartilage lesions of talus.

We use BMAC and GF combined with a biologic scaffold (ChondroGide®-Geistlich Wolhusen, CH) for full thickness cartilage defects repair; the porous structure of the scaffold facilitates adhesion, proliferation and differentiation of MSC. Recently we have published the results in a group of patients active in sports, but not professional.[94] We prospectively followed up for 2 yrs 15 patients (15 knees) operated for grade IV cartilage lesions of the knee (mean lesion size 9.2 cm^2); all these patients have been transplanted using BMAC covered with a collagen-based membrane. Bone marrow was harvested from ipsilateral iliac crest and subjected to concentration and activation with Batroxobin solution (Plateltex® act-Plateltex SRO Bratislava, SK) in order to produce a sticky clot, which was implanted into the prepared cartilage defect (Figure 2A-C). The patients followed the same specific rehabilitation program for a minimum of 6 months. All the patients showed improvements in evaluation scores. Mean pre-op values were: VAS 5, IKDC subjective 41.73, KOOS Scores P=66.6/ S=68.3/ ADL=70/ SP=41.8/ QOL=37.2, Lysholm 65 and Tegner 2.07. At final follow up mean scores were: VAS 0.8, IKDC subjective 75.5, KOOS P=89.8/ S=83.6/ ADL=89.6/ SP=58.9/ QOL= 68, Lysholm 87.9 and Tegner 4.1. No adverse reactions or post-op complication were noted. MRI showed good coverage of the lesions. Four patients gave their consent for second-look arthroscopy (Figure 2D) but only 3 for a concomitant biopsy. Good histological findings were reported for all the specimens analyzed who presented many hyaline-like features.[94] These data and result from other Italian authors [93] using MSC implantation with a one-step procedure seem to be promising, showing good clinical outcomes at early follow up.

Rehabilitation

The postoperative rehabilitation program follows the principles of cartilage transplantation. Healing of a concomitant osteotomy procedure should be established by radiographic criteria before making progress to full-weight bearing. Associated procedures such as ligamentous reconstruction or meniscal transplantation should also be considered. The rehabilitation protocol should be based on functional rather than temporal criteria; the progression of the recovery was related to the achievement of specific criteria that allow the patient to proceed to the next rehabilitative phase.[95-97] The protocol after cartilage transplantation includes 4 stages.[98]

From a functional point of view in our protocol we have identified different phases characterized by micro-objectives, which end with the achievement of specific functional criteria as set out at the beginning of each stage (Table II). The first 6 to 8 weeks after surgery are important for the healing process of the repaired chondral defect and continuous passive motion (CPM) is prescribed in order to avoid arthrofibrosis. We suggest a gradual increase of the knee flexion up to 90° and progressive recovery of range of motion. Partial weight bearing with crutches is allowed after the first few weeks and our protocol emphasizes the recovery of strength and proprioceptive abilities. An important part of the rehabilitation is the recovery of athletic general conditions and recovery of walking, running and sport activity are allowed according to specific clinical parameters and functional objectives.

Return to play time for high impact and pivoting sports varies widely, from as short duration as three months for OATS procedures to up to eighteen months for ACI. However, Kreuz *et al.*[99] stressed that "moderate sports" after ACI actually improved functional outcome for at least two years postoperatively; DellaVilla *et al.*[100] went further to suggest that an intensive rehabilitation protocol following MACI in athletes which included isokinetic and on-field activities positively affected graft maturation and shortened return to play time. However, it should be noted that all techniques stress at progressive functional return to sport-

TABLE II.—*Rehabilitation protocol.*

Phase	Objectives	Durance (estimated)
1	*Protection of the implant* Decrease pain and effusion Retard muscle atrophy Gain full extension and gradual recovery of knee flexion	0-6 weeks
2	*Transition and recovery of gait/ADL* Return to normal gait pattern / daily functional activities Increase the strength of the quadriceps and flexors Recovery of full range of motion	6-12 weeks
3	*Maturation and functional recovery/ running* Return to a correct running pathway Further increase in muscle strength Further increase in functional activities level	12-24 weeks
4	*Turnover and sports recovery* Sustain high loads and impact activities Prepare athlete for a return to team and competition Maintain a good quality of life/preventing risk of re-injury	24-52 weeks

specific play, dependent on the response and progress of the individual athlete.

Conclusions

Significant progress has been made in research and clinical application in the surgical treatment of articular cartilage defects in the competitive athlete. Although a variety of techniques are now available for the orthopedic biologic sports surgeon, as yet no gold standard exists for the treatment of articular cartilage injuries in high-performance professional athletes. Certain common treatment principles exist: Earlier diagnosis, shorter duration of preoperative symptoms, smaller lesions, younger age of athlete and intensive, cautious and individualized rehabilitation before return to play are favorable prognostically. Advanced techniques are available around the globe. Hopefully the continued research in this rapidly developing field will promise future athletes not only quicker functional return to play but also limit the long-term disability now associated with this problem.

Riassunto

Tecniche di riparazione cartilaginea negli atleti

Le lesioni cartilaginee del ginocchio negli atleti rappresentano una difficile sfida e possono essere la causa di invalidità permanente a causa degli importanti stress funzionali cui è sottoposta questa articolazione nell'atleta. Il trattamento dei difetti condrali nell'atleta è complesso e multifattoriale. Varie tecniche sono state sviluppate per trattare queste lesioni e la ricerca è sempre attiva nel cercare di migliorare i risultati. Le tecniche impiegate vanno dalle infiltrazioni intra-articolari con acido ialuronico e concentrati piastrinici fino a metodiche piu' invasive quali ACI, OATS, MACI e le microfratture. Recentemente il ruolo delle cellule mesenchimali stromali derivate dal midollo osso è stato ampiamente esplorato mostrando buoni risultati preliminari. Indipendentemente dalla tecnica impiegata un ruolo estremamente importante è rappresentato dalla riabilitazione postoperatoria. Vi sono pochi elementi con che supportino con grande evidenza la scelta di una tecnica rispetto ad un'altra sebbene buoni risultati a breve e medio termine con un ritorno parziale all'attività sportiva pre operatoria possono essere ottenuti con le tecniche di rigenerazione cartilaginea.

Parole chiave: Atleti - Cartilagine - Concentrati piastrinici - Cellule mesenchimali.

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