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Autologous Osteochondral Transplantation for Treating Patellar Chondral Injuries

Evaluation, Treatment, and Outcomes of a Two-Year Follow-up Study

Diego Costa Astur, MD, Gustavo Gonçalves Arliani, MD, Mario Binz, MD, Nelson Astur, MD, Camila Cohen Kaleka, MD, Joicemar Tarouco Amaro, MD, Alberto Pochini, MD, and Moises Cohen, MD, PhD

Investigation performed at the Universidade Federal de São Paulo, São Paulo, Brazil

Background: The patella is the largest human sesamoid bone and often sustains chondral injury. There is no consensus on how to treat a full-thickness, symptomatic articular cartilage injury of the patella. We analyzed the clinical and functional outcomes of patients with symptomatic full-thickness patellar chondral lesions treated with autologous osteochondral transplantation and evaluated osteochondral autograft bone-plug integration through magnetic resonance imaging.

Methods: In this prospective study, thirty-three patients with a symptomatic full-thickness patellar chondral injury surgically treated with autologous osteochondral transplantation were evaluated before and after surgical treatment with a minimum two-year follow-up using the Lysholm, Kujala, and Fulkerson questionnaires and the Short Form-36 health survey score. Magnetic resonance images were made at six and twelve months postoperatively and studies were performed to analyze the osteochondral autograft bone-plug integration.

Results: All thirty-three patients showed a significant improvement in functional scores two years after surgery. The average Lysholm scores were 57.27 points preoperatively and 80.76 points at two years postoperatively, the average Kujala scores were 54.76 points preoperatively and 75.18 points at two years postoperatively, and the Fulkerson average scores were 54.24 points preoperatively and 80.42 points at two years postoperatively. The Short Form-36 life quality score improved significantly. Two years after surgery, all magnetic resonance images showed full bone-plug integration into the patella.

Conclusions: Autologous osteochondral transplantation is a successful technique to surgically treat symptomatic full-thickness patellar articular cartilage injuries smaller than 2.5 cm in diameter. Patients had a significant improvement in clinical scores. Bone-plug integration and surface alignment were demonstrated in all patients two years after surgery.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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Articular cartilage injuries are challenging to treat because the likelihood of tissue regeneration is relatively low[1]. Articular cartilage injury is common in the knee, seen in 63% of knee arthroscopies[2]. This injury can lead to knee pain, joint swelling, and, eventually, development of early osteoarthrosis[3].

The patella is a sesamoid bone with the thickest cartilaginous surface in the human body. This large thickness increases the articular surface area as well as the patellofemoral joint load-sharing distribution[4-6]. The load generated at the patellofemoral joint with our daily activities can reach 6.5 times our body mass[7]. Any full-thickness chondral injury in the patella prevents a normal distribution of these forces, leading to propagation of chondral tear, increased pain, and functional impairment[5]. Consequently, osteochondral defects in the patella are difficult injuries to treat[8].

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TABLE I Preoperative and Postoperative Functional Results (N = 33)

Variable	Functional Results: Average*	Functional Results: Median†	P Value
Lysholm			<0.001
Preoperative	57.27 ± 19.97	58 (9 to 98)	
Postoperative	80.76 ± 12.26	85 (51 to 99)	
Fulkerson			<0.001
Preoperative	54.24 ± 18.89	56 (2 to 93)	
Postoperative	80.42 ± 10.20	82 (49 to 95)	
Kujala			<0.001
Preoperative	54.76 ± 17.61	58 (10 to 81)	
Postoperative	75.18 ± 12.47	77 (49 to 97)	

*The values are given as the average and the standard deviation in points. †The values are given as the median in points, with the range in parentheses.

In recent decades, various treatment options have emerged to treat these injuries, with varying success[1,8-17]. Non-surgical treatment may relieve pain[18] but surgical treatment has the advantage of restoring the articular cartilage surface. Among surgical techniques, three have demonstrated good results: microfracture, autologous chondrocyte implantation, and autologous osteochondral transplantation[19].

Autologous osteochondral transplantation restores a stable height and articular surface shape using an autologous graft, with less fibrocartilaginous filling of the defect[14]. Autologous osteochondral transplantation has been used to treat cartilaginous femoral, trochlear, and condylar defects, but its application in patellar chondral injury is still underreported and inaccurate[8,11,12,17,20].

The purpose of this study was to analyze clinical and functional outcomes of patients with a symptomatic full-thickness patellar chondral lesion treated with autologous osteochondral transplantation and to evaluate osteochondral anatomical autograft bone-plug integration within the patella through T2 relaxation time-mapping magnetic resonance imaging (MRI).

Materials and Methods

With institutional review board approval, a prospective study was undertaken in the period from 2008 to 2010. A total of thirty-three patients (seventeen male patients and sixteen female patients) with a symptomatic full-thickness patellar articular cartilage injury underwent an autologous osteochondral transplantation performed by the senior author (M.C.). Data were collected and were evaluated in accordance with hospital policies (see Appendix).

Patients were included in the study if they were less than sixty years of age and had anterior knee pain, a Grade-III or IV chondral lesion (according to the International Cartilage Repair Society classification), and cartilaginous injury sized 1 to 2.5 cm in diameter[21]. Patients were excluded if they had injuries sized <1 cm or >2.5 cm in diameter, a patellar tilt abnormality, a patella alta or a patella baja, a >15-mm distance of the tibial tubercle and trochlear groove, an associated anterior cruciate ligament injury in need of surgical reconstruction, a meniscal tear, an infection, and/or a systemic inflammatory disease.

Preoperative Evaluation

Patients with anterior knee pain were clinically evaluated and, when a patellar cartilaginous injury was suspected, knee radiographs were made to analyze the presence of a patellar tilt through a Merchant view[22], which can quantify the sulcus and congruence angles, and to analyze patellar height through a lateral radiograph. Patellar height was quantified through the Insall-Salvati method[23], which measures both patellar tendon length and patellar greater axis. Patients then underwent a computed tomography (CT) scan to analyze patellar and trochlear morphology, as well as patellar alignment through the tibial tubercle-trochlear groove measurement, which is the distance between the tibial tubercle and the trochlear groove with a normal value in full knee extension between 10 and 15 mm[24,25].

Finally, MRI of the knee was performed to diagnose and to characterize the chondral defect. After informed consent, if all inclusion criteria were met, patients underwent the surgical procedure described next.

Description of Procedure (Patellar Autologous Osteochondral Transplantation)

Patients were prepared in the standard fashion. A standard arthroscopic joint evaluation was carried out, confirming the patellar articular cartilage injury diagnosis. Once the defect was located, the arthroscopy procedure was stopped and a parapatellar longitudinal approach was performed from the apex of the patella to its inferior edge. This approach could be medial or lateral parapatellar depending on which patellar facet was injured (Fig. 1-A).

After subcutaneous dissection to expose the articular capsule, an arthrotomy was carried out and the patella was inverted to provide excellent visualization of the articular surface. A Kirschner wire was used as a joystick for better exposure of the defect (Fig. 1-B). At that point, the diameter of the chondral injury was measured with a metric guide, from which the size of the osteochondral cylinder from the donation site was determined (Fig. 1-C). The graft harvester device was a millimeter greater in diameter than the device designated to pierce the receiving site. The previously measured defect was drilled with a burr device within the size of the designed diameter (Figs. 1-D and 1-E). The average height of the graft cylinder was 10 mm. With the knee flexed, the receptor tunnel was enlarged, followed by harvesting of the osteochondral graft. The chosen donor site was within a surrounding non-load-bearing zone, superior to the femoropatellar articular area (Figs. 1-F and 1-G). All drillings were performed perpendicular to the joint surface. The osteochondral cylinder was then implanted (Fig. 1-H) until its surface was level with the surrounding articular cartilage (Fig. 1-I).

Postoperative Rehabilitation

Rehabilitation was immediately started with the Bobić[26] and Hangody et al.[27] protocols for all patients. These protocols involve early exercises to improve knee motion on a hard surface and in water. Gait training in deep water started

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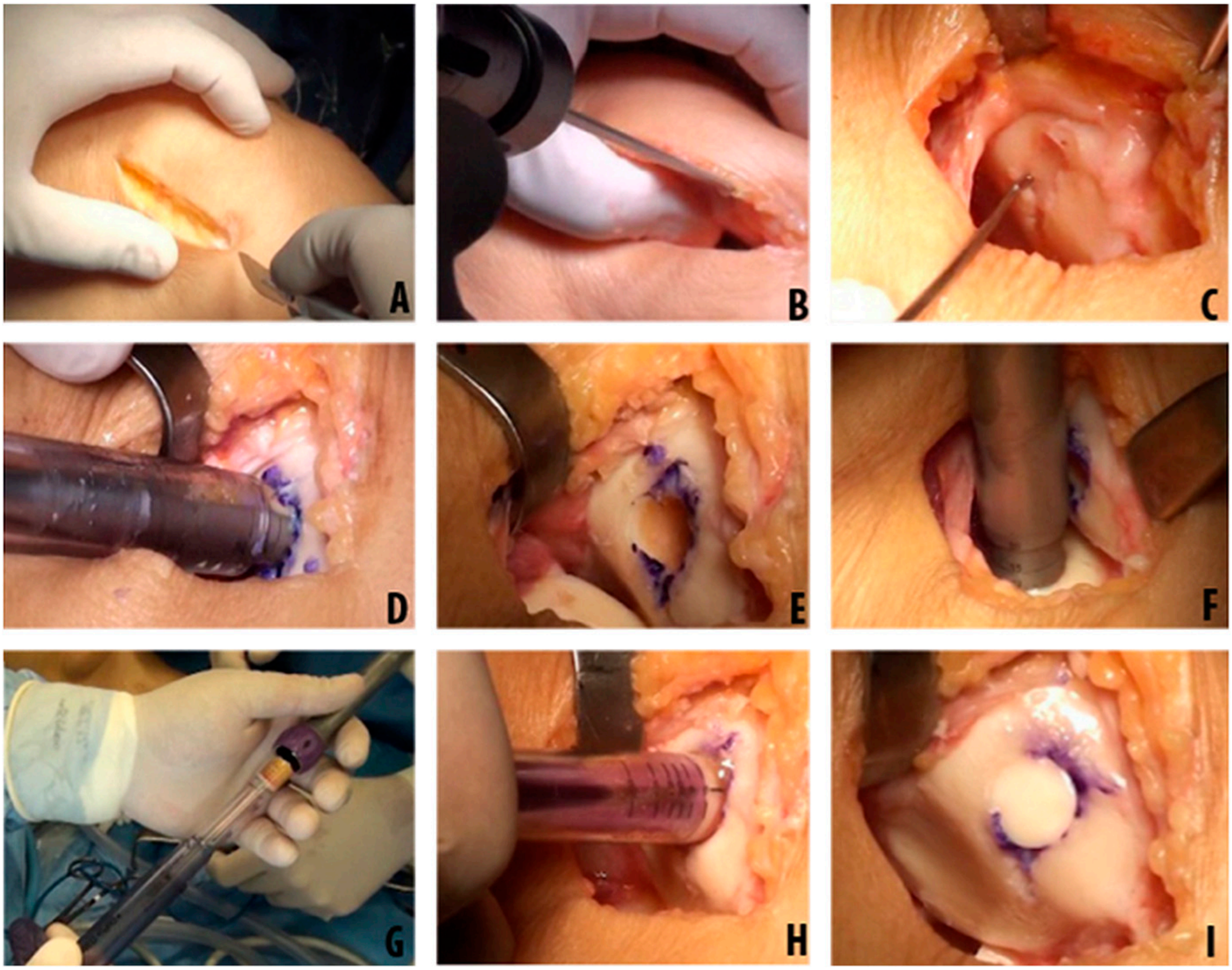

Fig. 1

Intraoperative photographs showing the surgical technique for autologous osteochondral transplantation in a patellar chondral injury. **Fig. 1-A** Incision and medial parapatellar arthrotomy. **Fig. 1-B** Kirschner wire fixation working as a joystick. **Fig. 1-C** Identification of the osteochondral injury at the medial facet of the patella. **Fig. 1-D** Debulking of the injured site with proper devices. **Fig. 1-E** Receptor site. **Fig. 1-F** Osteochondral graft harvesting at the superior aspect of the medial femoral condyle, outside the load-bearing region. **Fig. 1-G** Osteochondral plug graft before its implantation. **Fig. 1-H** Plug implantation at the receptor site. **Fig. 1-I** Final view of the procedure showing adequate defect-filling cartilaginous surface alignment.

immediately and, after three to four weeks of exercise on a stationary bicycle, progressive muscular strengthening and sensorimotor training and stretching were instituted. The patient was allowed to partially bear weight on the involved lower extremity for two to three weeks, and running was allowed after four to six months. High-functional-demand sports were allowed after six months.

Clinical and Functional Evaluations

We compiled data on basic patient characteristics, surgical details, and complications. A minimum follow-up of twenty-four months was required. Study participants were assessed preoperatively and at two years postoperatively by an independent orthopaedic surgeon (D.C.A.). The preoperative and postoperative outcomes included evaluations with specific knee function questionnaires, including those of Kujala[28], Fulkerson[29], and Lysholm[30], as well as the Short Form-36 (SF-36) health survey score. The Kujala scale evaluates subjective symptoms such as anterior knee pain and functional limitations of patellofemoral syndromes. The Lysholm scale is a 100-point scale based on subjective, objective, and functional items on knee instability. The SF-36 questionnaire consists of eight scaled scores directly transformed into a 0-to-100 scale to measure health status or quality of life. Higher scores indicate higher levels of health.

Patients also routinely underwent a standard MRI and a T2 relaxation time-mapping MRI study of the involved knee at six and twelve months after surgery to evaluate osteochondral bone-plug integration. Although routine MRI allows a subjective assessment of cartilage changes, quantitative T2 mapping provides objective data by creating a color map representation of the cartilage variations in relaxation time. Imaging can be classified into four different grades: Grade I has a predominant color of blue, Grade II is mainly green, Grade III is yellow, and Grade IV is red. Grades III and IV are similar to normal cartilage and Grades I and II represent pathological changes on the cartilaginous surface. The grade of the plugs' chondral surface was compared with its surrounding normal chondral surface in an area of 0.5 cm around the injury site. We considered bone-plug integration when both the plugs' chondral surface and its surroundings had similar colors (Grades III and IV). The color maps are coded to capture T2 values

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TABLE II Preoperative and Postoperative SF-36 Results (N = 33)

Variable	Results		P Value‡
	Average*	Median†	
Physical function			0.006
Preoperative	45.91 ± 13.31	50 (25 to 75)	
Postoperative	63.64 ± 29.11	70 (10 to 95)	
Role physical			0.001
Preoperative	43.94 ± 35.37	50 (0 to 100)	
Postoperative	73.48 ± 32.44	75 (0 to 100)	
Body pain			<0.001
Preoperative	51.73 ± 20.98	51 (21 to 100)	
Postoperative	72.30 ± 24.01	78 (20 to 100)	
General health			0.214
Preoperative	73.45 ± 17.86	72 (47 to 100)	
Postoperative	77.79 ± 17.51	82 (37 to 100)	
Vitality			0.004
Preoperative	61.97 ± 22.08	60 (20 to 95)	
Postoperative	75.45 ± 18.13	80 (25 to 95)	
Social function			0.017
Preoperative	61.70 ± 15.91	62 (38 to 100)	
Postoperative	73.71 ± 21.92	80 (20 to 100)	
Role emotional			0.016
Preoperative	44.18 ± 36.60	37.5 (0 to 100)	
Postoperative	73.99 ± 41.22	100 (0 to 100)	
Mental health			0.049
Preoperative	65.58 ± 17.03	64 (40 to 100)	
Postoperative	74.06 ± 21.24	84 (20 to 100)	

*The values are given as the average and the standard deviation in points. †The values are given as the median in points, with the range in parentheses. ‡The p values were based on paired Wilcoxon test results; there were significantly improved postoperative scores in seven of the eight criteria analyzed.

ranging from 20 to 70 ms. Morphologic MRI provided analysis of the chondral thickness maintenance and the reintegration tissue in between both surfaces. The appearance of Grades III and IV at the plug site and around it indicates successful integration and is a sign of emergence of a collagen network with the shape and overall organization similar to those seen in normal articular cartilage[8,31-33].

Statistical Analysis

All preoperative and postoperative questionnaire scores were analyzed through the nonparametric Wilcoxon paired test. When analyzing the questionnaires' correlation, the Spearman test was applied. Our sample was divided according to the number of osteochondral graft plugs inserted (one or two plugs), defect size (lesions above and below 2 cm), and patellar facet affected (lateral and medial lesions, lateral lesions, medial lesions, and central lesions). To compare postoperative questionnaire scores between subgroups, the Mann-Whitney or Kruskal-Wallis tests were applied. Significance for the whole analysis was set at $p < 0.05$.

Source of Funding

There was no external funding source.

Results

From July 2008 to December 2010, we evaluated the involved knees of thirty-three patients who underwent an autologous osteochondral transplantation for a symptomatic full-thickness cartilaginous injury on the patellar articular surface. No patient was lost during follow-up. There were seventeen male patients and sixteen female patients. The median length of follow-up was 30.2 months (range, twenty-four to fifty-four months). The mean patient age was 37.6 years (range, sixteen to fifty-nine years).

Twenty-eight knees had only a single 10 × 15-mm osteochondral graft implanted. Only five knees required two graft cylinders.

In thirteen patients (39.4%), the lateral patellar facet was injured. Another thirteen patients (39.4%) had a medial facet injury. Five patients (15.2%) had a defect in both the lateral and medial facets and only two patients (6%) had an injury in the central area of the patellar articular surface (see Appendix).

The average Lysholm score (and standard deviation) was 57.27 ± 19.97 points preoperatively and 80.76 ± 12.26 points postoperatively ($p < 0.05$). The average Fulkerson score (and standard deviation) was 54.24 ± 18.89 points preoperatively and 80.42 ± 10.20 points postoperatively ($p < 0.05$). The average Kujala score (and standard deviation) was 54.76 ± 17.61 points

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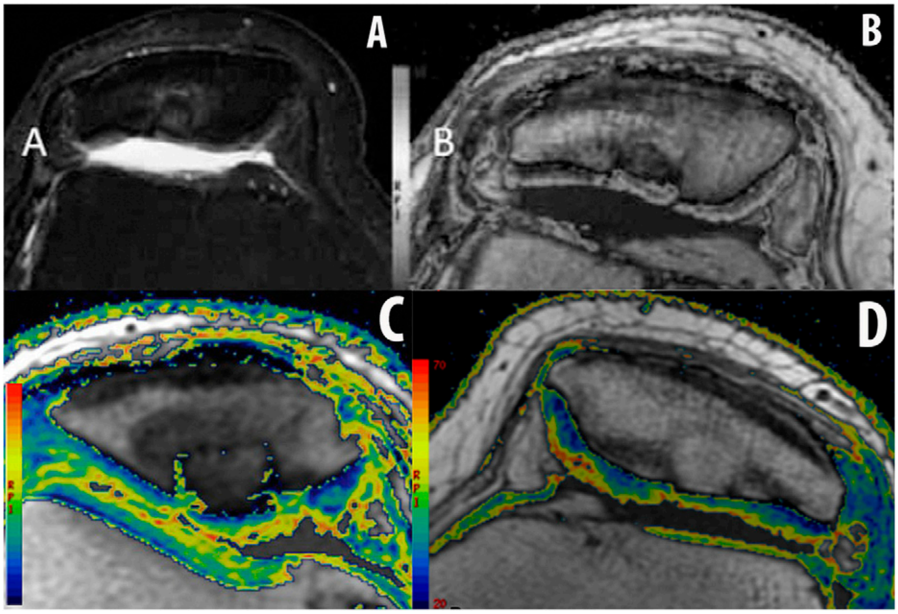

Fig. 2

MRIs of three different patients showing the osseous integration of the bone plug after surgery. Integrity of cartilage resurfacing in an axial T2 standard MRI in a thirty-year-old patient with a patellar autologous osteochondral plug six months (**Fig. 2-A**) and twelve months (**Fig. 2-B**) after surgery and in an axial T2 relaxation time-mapped MRI in a thirty-two-year-old patient with a patellar autologous osteochondral plug without complete integration six months after surgery (**Fig. 2-C**) and in a twenty-year-old patient with an integrated patellar autologous osteochondral plug twelve months after surgery (**Fig. 2-D**). The color maps are coded to capture T2 values ranging from 20 to 70 ms, with blue and green reflecting shorter values and yellow and red (more normal) reflecting longer T2 values. After twelve months, the repair cartilage maintains color stratification of normal cartilage.

preoperatively and 75.18 ± 12.47 points postoperatively ($p < 0.05$) (Table I).

There was a significant difference ($p < 0.05$) between preoperative and postoperative analyses of the SF-36 subscales (Table II). When the analysis among specific evaluations of the SF-36 subscales and all others knee questionnaires was performed, there was a correlation between the best scores for the Kujala questionnaire with role physical, body pain, and social function ($p < 0.05$); for the Lysholm questionnaire with body pain and general health ($p < 0.05$); and for the Fulkerson questionnaire with body pain and general health ($p < 0.05$) (Table III).

Because we had significant superior results in our patients' postoperative evaluations, a comparison was performed among lesion size, location, and plugs inserted. There was no significant difference between patients with lesions below 2 cm and those above 2 cm in diameter. To compare postoperative scores and various patellar facet groups, both subjects with central lesions were excluded because of the small number of patients[34]. A multiple-comparison test was applied for the Lysholm questionnaire, the only one with significance between groups ($p < 0.05$). Results were significant for lesions at the lateral facet compared with the lateral and medial facets ($p < 0.05$). There was no significant difference ($p > 0.05$) on comparisons among other sites of facet injury (medial compared with medial and lateral; medial compared with lateral). Lysholm score analysis showed better results in patients who had a single osteochondral plug inserted compared with those with more than one plug inserted ($p < 0.05$). There was no significance for the other scores (see Appendix).

Six months after surgery, 83% of the plugs had complete osseous integration, which increased to 100% one year postoperatively, according to conventional MRI (no articular surface incongruence was noted) supplemented with a T2 relaxation time-mapping technique (Grades III and IV for the plugs' surface and its surroundings) (Fig. 2).

The complication rate was 9% (three patients), all because of arthrofibrosis of the knee. They were all successfully treated with an arthroscopic release. There were no intraoperative complications.

Discussion

Patellar chondral injuries have always been challenging to treat and no prior surgical technique has been reported with good or excellent functional results. The current available techniques present disadvantages or suboptimal outcomes. Autologous osteochondral transplantation, first reported in 1964 by Wagner[35], creates an immediate cartilaginous articular surface congruency in a single procedure through the implantation of an osteochondral plug.

Few studies have shown the results of the autologous osteochondral transplantation technique to treat patellar chondral injuries[8,36]. Most are case reports or series of cases with limited statistical analysis. Difficulties of this technique include the limited access to the injury, greater thickness of patellar cartilage as compared with other anatomic sites, and the many associated

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TABLE III Correlation of Lysholm, Fulkerson, and Kujala Scores with the Subscales of SF-36 (N = 33)

	Correlations		
SF-36 Subscales*	Lysholm	Fulkerson	Kujala
Physical function			
r	0.202	0.138	0.331
p	0.260	0.445	0.060
Role physical			
r	0.009	0.130	0.518
p	0.961	0.470	0.002
Body pain			
r	0.361	0.396	0.383
p	0.039	0.023	0.028
General health			
r	0.493	0.434	0.316
p	0.004	0.012	0.073
Vitality			
r	0.272	0.345	0.215
p	0.125	0.049	0.229
Social function			
r	0.190	0.176	0.480
p	0.289	0.329	0.005
Role emotional			
r	0.298	0.184	0.274
p	0.093	0.305	0.123
Mental health			
r	0.265	0.536	0.304
p	0.137	0.001	0.085

*The Spearman correlation number is represented by r and the lower or upper confidence bound is represented by p.

problems that can lead to an articular cartilage injury in the patella. Bentley et al. reported that the difference between the cartilage thickness of the patella and the plug donation site would compromise the graft integration, nullifying this technique to treat injuries of the patella[17].

Analysis on our patients' follow-up MRI demonstrated satisfactory intermediate imaging results as there was integration of all plugs, disproving the conclusion of Bentley et al. Postoperative imaging is recommended to assess the technical success of the procedure and the grade of cartilage healing, as well as to identify potential complications. MRI allows a more comprehensive evaluation of tissue repair than does arthroscopy, from the articular surface of the joint to the bone-cartilage interface. MRI evaluation of a transplanted osteochondral autograft should include assessments of the degree of defect filling by the osteochondral plug, peripheral integration of reparative cartilage and bone, cartilage surface contour, and morphological characteristics of the autologous bone[37]. For this reason, we chose a T2-mapping MRI sequence of our patients, which is more sensitive for a quantitative evaluation of the lesion as well as cartilage regeneration when performed alongside a traditional MRI technique[8,32,33,37-39]. The ability to assess cartilage characteristics through a four-colored scale resulted in a more accurate definition of optimal bone-plug integration, as well as cartilaginous continuity along the bone-plug surface. When properly placed, we experienced no difficulties in achieving integration of the osteochondral plugs (Fig. 2). Twelve months post-surgery, all patients had Grade-III and IV MRI for the injury site. These are signs of collagen fiber integration in between different surfaces.

Analysis of the Lysholm, Kujala, and Fulkerson questionnaire scores demonstrated an improvement of the patients' knee function and pain when their preoperative and postoperative results were compared. The same improvement was observed in patients' quality of life with SF-36 score improvement. Nho et al. reported twenty-two cases of autologous osteochondral transplantation to treat patellar cartilage injuries, where an improvement in functional scores was also noted. These same authors also analyzed postoperative imaging studies in fourteen of their patients four months after surgery. There was adequate filling of the cartilage gap (67% to 100%) as well as adequate integration of the osteochondral plug (71%)[8]. Our integration rate was 83% at six months postoperatively and 100% at twelve months postoperatively. Nho et al. suggested that patients with patellar malalignment had worse clinical results than those with a normal patellar alignment, highlighting the importance of proper patient selection for this technique. In the present study, patients with a patellofemoral malalignment were excluded because we believe that these subjects should have the malalignment treated before the chondral lesion. Vasiliadis et al. analyzed patients with cartilaginous injuries treated with chondrocyte autologous transplantation and concluded that correcting the coexisting risk factors improves the clinical outcomes over time[40]. For this reason, all patients underwent radiographic, tomographic, and MRI studies preoperatively. Other studies that applied different subjective knee function scales preoperatively and postoperatively demonstrated improvement of those scores after surgical treatment with the autologous osteochondral transplantation technique for patellar chondral injuries[12,35,41]. However, there was a single study that compared the results of this technique to treat patellar chondral injuries and femoral condyle chondral injuries[11]. Postoperative patellar outcomes were inferior to results for the femoral condyle. We emphasize the importance of a complete evaluation of the patient's injury and the indication of this technique just for specific situations.

To our knowledge, there is no study comparing different techniques to treat a cartilaginous injury of the patella. The existence of different injury types to indicate a specific technique such as microfracture or autologous chondrocyte transplantation makes it difficult to obtain a similar sample of patients for a comparative study. This may be the reason for a scarce number of randomized clinical trials available comparing surgical techniques for cartilaginous injury treatment. Thus, an optimal technique to treat most cases of patellar chondral injury is difficult to conclude. The advantages of our

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study were the large number of patients compared with those in the current literature treated at a single institution with a minimum two-year follow-up. The limitations of this study were the difficulty of obtaining homogeneous samples of patients with the same type of lesion to compare this technique with others previously reported, as there was no control group in this series.

In summary, autologous osteochondral transplantation is a successful technique to surgically treat symptomatic full-thickness patellar articular surface chondral injuries <2.5 cm in diameter. Patients had a significant improvement in clinical scores and plug integration was demonstrated by MRI in all patients by two years after surgery.

Appendix

eA Tables showing patient characteristics and a comparison among lesion characteristics, lesion treatment types, and postoperative questionnaires are available with the online version of this article as a data supplement at jbjs.org. ■

Diego Costa Astur, MD
Gustavo Gonçalves Arliani, MD
Mario Binz, MD
Nelson Astur, MD
Camila Cohen Kaleka, MD
Joicemar Tarouco Amaro, MD
Alberto Pochini, MD
Moises Cohen, MD, PhD
Universidade Federal de São Paulo,
Rua Borges Lagoa 783,
5° andar, São Paulo,
Brazil 03840-032.
E-mail address for D.C. Astur: mcastur@yahoo.com

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