One-Step Repair in Talar Osteochondral Lesions: 4-Year Clinical Results and T2-Mapping Capability in Outcome Prediction

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One-Step Repair in Talar Osteochondral Lesions

4-Year Clinical Results and T2-Mapping Capability in Outcome Prediction

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Background: A recent one-step arthroscopic technique based on bone marrow–derived cell transplantation has achieved good results in repairing osteochondral lesions of the talus (OLTs), overcoming some of the drawbacks of older techniques.

Purpose: To report the results after 4 years of a series of patients who underwent a one-step repair of osteochondral lesions of the talar dome, as well as the capability of magnetic resonance imaging (MRI) using a T2-mapping sequence to predict the clinical outcome.

Study Design: Case series; Level of evidence, 4.

Methods: Forty-nine patients (age [mean ± SD], 28.08 ± 9.51 y) underwent a one-step repair of OLTs. Patients were evaluated clinically by American Orthopaedic Foot and Ankle Society (AOFAS) scores and radiographs and underwent MRI preoperatively and during postoperative follow-ups at predetermined times. In all patients, the cells were harvested from the iliac crest, concentrated, and loaded on a scaffold that was implanted arthroscopically.

Results: The overall AOFAS score (mean ± SD) improved from 63.73 ± 14.13 preoperatively to 82.19 ± 17.04 at 48 ± 6.1 months ($P < .0005$), with best results at the 24-month follow-up. A significant decrease in the clinical score was observed between 24 and 36 months postoperatively ($P = .001$) and between 24 and 48 months ($P < .005$). The T2-mapping analysis showed regenerated tissue with T2 values of 35 to 45 milliseconds, similar to hyaline cartilage, in a mean of 78% ± 16% of the repaired lesion area. The time between the occurrence of trauma and surgery was found to negatively affect the clinical outcome at the latest follow-up; patient's age and lesion size influenced the early clinical results but did not affect the outcome at final follow-up. The stability of clinical results over time and the percentage of tissue with values similar to hyaline cartilage evidenced by MRI T2 mapping showed a tendency to correlate at the last follow-up ($r = 0.497$, $P = .06$).

Conclusion: One-step repair of OLTs had good clinical results that were durable over time, even though there was a slight decrease in AOFAS score at the latest follow-up. The quality of the regenerated tissue detected by MRI T2 mapping directly correlated with the clinical results.

Keywords: BMDCT; one-step technique; cartilage regeneration; osteochondral lesion; MRI T2 mapping

Osteochondral lesions of the talus (OLTs) occur frequently in young active patients and can be difficult to treat.[6,28,30] Chondral tissue has poor healing abilities[1]; therefore, the damage may be irreversible[8] and lead to chronic symptoms and early osteoarthritis.[2,9,18,26]

Clinical results and durability over time of the repaired tissue are believed to be strictly dependent on the quality of the regenerated cartilage.[3] Over time, various surgical options have been proposed to restore an adequate cartilaginous layer on the talar dome, but among them, only autologous chondrocyte implantation (ACI) has shown the ability to regenerate hyaline cartilage.[3,22] More recently, a one-step bone marrow–derived cell transplantation (BMDCT) technique has been proposed as an alternative capable of repairing the lesion with hyaline cartilage,[15] with the advantage of being a completely arthroscopic single-step technique.[10,15] Histological results

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of the repaired area by the one-step technique have been previously provided, confirming the regeneration of articular cartilage in the remodeling phase with hyaline features.[11]

Second-look biopsy of the repaired tissue is invasive and able to evaluate just the focal area. As an alternative, magnetic resonance imaging (MRI) is a noninvasive method capable of providing important structural information about the entire repaired area, such as percentage of the defect filling, integration of the reparative tissue with the surrounding cartilage at the lesion edge, and integrity of the surface.[11] In particular, MRI using T2-mapping sequences[17,25] is able to discriminate the qualitative nature of the reparative tissue based on the interaction of water molecules and the collagen network within regenerated cartilage.[4,5,13,14]

The aim of this study was to report the clinical results at 4-year follow-up of a series of patients who underwent a one-step procedure for osteochondral repair in the ankle joint and to determine the capability of T2 mapping to predict the final outcome obtained.

MATERIALS AND METHODS

From October 2005 to June 2007, we enrolled 49 patients (mean ± standard deviation [SD] age, 28.08 ± 9.51 y; follow-up time, 48 ± 6.1 mo; range, 36-54 mo) affected by focal osteochondral lesions of the talar dome to be treated with BMDCT using a one-step arthroscopic technique. In the same period, a total of 67 patients were treated with the same surgical technique, but only 49 patients were enrolled (73.1%) because 18 patients did not match the inclusion criteria and were not eligible for this study. Some of these patients had been evaluated in a previous study at different follow-ups.[15] The treatment was indicated for focal osteochondral lesions of the talar dome classified as chronic type II (>1.5 cm^2 in area, <5 mm deep), according to the Giannini classification.[14] We excluded patients younger than 14 years or older than 50 years, patients with osteoarthritis or kissing lesions of the ankle, and patients with rheumatoid arthritis. Malalignments of the lower limb and the presence of joint laxity were considered relative contraindications to be corrected if present. Inclusion and exclusion criteria were ensured by independent evaluation of the patients by the authors (M.C. and F.V.).

Twenty-seven patients were male and 22 were female. Mean lesion size was 2.24 ± 1.23 cm^2, and the depth was 3.9 ± 0.9 mm. In 22 patients, the lesion was in the right ankle and in 27 it was in the left ankle; the lesion was located medially in 39 cases and laterally in 9, and in only 1 case, it involved both the medial and the lateral aspects of the talar dome. In 36 patients, the lesion had a definite posttraumatic origin, and the time elapsed between trauma and the treatment ranged from 2 months to 18 years. Four patients had a previous ankle fracture, and 32 had a previous ankle sprain without a fracture, whereas 13 were not able to recall a specific traumatic event of the affected ankle. Seventeen patients had been treated previously by arthroscopic ankle debridement (n = 8), microfracture (n = 5), ACI (n = 2), or BMDCT (n = 2).

The ethical committee of our institution approved the human protocol for this investigation. All investigations were conducted in conformity with ethical principles of research, and written informed consent was provided by all the patients enrolled in this study.

Surgical Technique

The surgical technique has previously been described.[15] Briefly, the patient was placed in the prone position after general or spinal anesthesia was induced. The bone marrow was harvested from the posterior iliac crest using a sterile technique. A total of 60 mL of bone marrow aspirate was collected and inserted into a concentrator-separator device (Smart PReP, Harvest Technologies Corp, Plymouth, Massachusetts). After a 15-minute working cycle, the aspirate was reduced in volume to obtain 6 mL of bone marrow concentrate rich in nucleated cells. During the concentration process, a standard ankle arthroscopic procedure was performed, and the lesion site was visualized and prepared until the healthy bone was reached. With a probe, we measured the lesion size in millimeters. The composite to be implanted was prepared by loading collagen powder (Spongostan Powder, Johnson & Johnson Medical Ltd, Gargrave, United Kingdom), which becomes a malleable paste once mixed with autologous cell concentrate and platelet gel (first 23 patients), or a hyaluronic acid membrane (HYAFF-11, Fidia Advanced Biopolymers, Abano Terme, Italy)[7] with 2 mL of bone marrow concentrate and 1 mL of autologous platelet gel (platelet-rich fibrin) (remaining 26 patients).[12,20,24,29] Using the same instrumentation previously described for arthroscopic ACI,[16] the composite was placed onto the lesion site. Multiple sagittal ankle movements were performed under arthroscopic control to verify the stability of the implant.

Patient Evaluation

An initial clinical and physical examination was completed on each patient. We recorded any known history of possible ankle trauma and any previous treatment. Preoperatively, 2 clinicians (F.V. and M.C.) examined the ankle for instability, malalignment, and range of motion, and patients were evaluated using the American Orthopaedic Foot and Ankle Society (AOFAS) score.[19] A standard radiographic examination including anteroposterior and lateral weightbearing views as well as MRI of the affected ankle were taken preoperatively.

Patients were asked to return for re-evaluation at 6, 12, 18, 24, 36, and 48 months after surgery. Clinical evaluation was performed in all cases at 6 months and every year after surgery for up to 36 months. Only 41 patients reached the 48-month follow-up. At each follow-up, the patient's

score was related to the maximum possible improvement, calculated as follows:

$$\text{Improvement percentage at a set follow-up} = [(\text{AOFAS score at the follow-up} - \text{AOFAS preoperative})/(100 - \text{AOFAS preoperative})] \times 100.$$

Standard MRI scans were taken at 12 and 24 months. At 24 months, a more detailed MRI evaluation was performed in 20 patients using the magnetic resonance observation of cartilage repair tissue (MOCART) scoring system[23] and T2-mapping sequences. Images were obtained using a 1.5-T magnetic resonance scanner (HDxt, General Electric, Chalfont St Giles, United Kingdom) and a dedicated phased array coil. The following sequences were used:

1. Coronal delayed-phase fast spin echo (DPFSE) high-resolution fat-saturated (repetition time [TR], 2700 ms; echo time [TE], 24 ms; field of view [FOV], 17; matrix, 416 × 416; gap spacing, 0; slice thickness, 2 mm; number of acquisitions, 2) and coronal DPFSE without fat suppression.
2. Coronal 3-dimensional spoiled gradient recalled echo (3D-SPGR) fat-saturated (TR, 325 ms; TE, 6 ms; flip angle, 20°; FOV, 17; matrix, 256 × 256; gap spacing, 0; slice thickness, 2 mm; number of acquisitions, 4).
3. Sagittal DPFSE high-resolution fat-saturated (TR, 1720 ms; TE, 24 ms; FOV, 17; matrix, 416 × 416; gap spacing, 0; slice thickness, 2 mm; number of acquisitions, 2).

The 3D-SPGR sequence of one patient was not considered because of the high amount of artifacts due to small ferromagnetic particles released by the shaver during surgery.

The MOCART score parameters considered for cartilage evaluation were (1) degree of filling of the osteochondral defect (complete, hypertrophic, incomplete inferior or superior to 50% of the defect, exposure of subchondral bone); (2) integration to the border zone (complete, incomplete); (3) surface of the repaired tissue (intact, damaged inferior or superior to 50% of the regenerated surface); (4) structure of the repaired tissue (homogeneous or inhomogeneous); (5) signal intensity of the repaired tissue in DPFSE fat-saturated sequences (isointense, moderately hyperintense, markedly hyperintense); (6) integrity of the subchondral lamina; (7) integrity of the subchondral bone; (8) adhesion of the regenerated tissue; and (9) presence of joint effusion. Both depth (mm) and volume of the regenerated defect (mm^3) were calculated with manual trace. The volume was calculated with the formula of the ellipsoid ($A \times B \times C \times 4/3\pi$).

For these 20 patients, the MRI acquisition protocol at 24-month follow-up was completed by coronal and sagittal T2-mapping high-resolution sequences (TR, 1000 ms; TE, 10-80 ms for study hyaline cartilage; FOV, 17; matrix, 256 × 256; gap spacing, 0; slice thickness, 2 mm; number of acquisitions, 1). The T2 mapping was a multiecho (8-echo train) and multislice (18-slice) sequence, with a total of 144 images acquired. It was necessary to use specific post-processing T2-mapping software (with final T2 grading color maps for normal and pathological hyaline cartilage) and to identify 2 presets (preset 1 = 10-50 ms; preset 2 = 51-80 ms) before proceeding with image elaboration.

Only coronal MRI views were considered for T2-mapping evaluation because of their higher chromatic homogeneity due to a lower "magic angle" in the artifact's influence.[31] Measurement of the spatial distribution of the T2 mapping revealed areas with increased or decreased water content. These areas were measured by manual trace for single acquired slices, and the percentage of altered tissue was related to the whole regenerated defect volume.

The considered T2 values were (1) percentage of regenerated tissue similar to hyaline cartilage (T2 values of 35-45 ms); (2) percentage of regenerated tissue with a higher water content, which was considered to be tissue in the remodeling phase or inflammatory tissue (T2 values of >45 ms); (3) percentage of regenerated fibrocartilaginous tissue (T2 values of <35 ms); and (4) percentage of regenerated newly formed bone.

Twenty healthy volunteers were used as controls to calculate the T2 values of healthy cartilage for comparison.[4] Results were analyzed by age, lesion size and depth, MOCART score, and T2-mapping evaluation of the regenerated tissue. Finally, a correlation analysis between 24-month MRI results and clinical scores (AOFAS) at the last follow-up of 48.8 ± 7 months was attempted. The imaging evaluation was performed independently by M.B. and F.V., while the clinical assessments were performed by M.C. and L.R.

Statistical Analysis

Age and clinical scores are expressed as mean ± SD, while all other parameters are expressed in terms of median values and ranges, under the hypothesis of nonnormality by the Kolmogorov-Smirnov test. A paired *t* test was used to assess differences among presurgical, postsurgical, and 24-month follow-up scores. The Mann-Whitney test was performed to test hypotheses about medians of the different groups. Spearman rank correlation analysis was used to assess correlations between continuous variables. For all tests, $P < .05$ was considered significant. Statistical analysis was carried out by means of SPSS software version 14.1 (SPSS Inc, Chicago, Illinois).

RESULTS

We had no intraoperative complications. Postoperatively, 1 patient had a superficial infection of an arthroscopic portal; the infection resolved with oral antibiotic therapy.

Clinical Outcomes

Overall, the preoperative AOFAS score was 63.73 ± 14.13. Postoperatively, a progressive improvement was observed

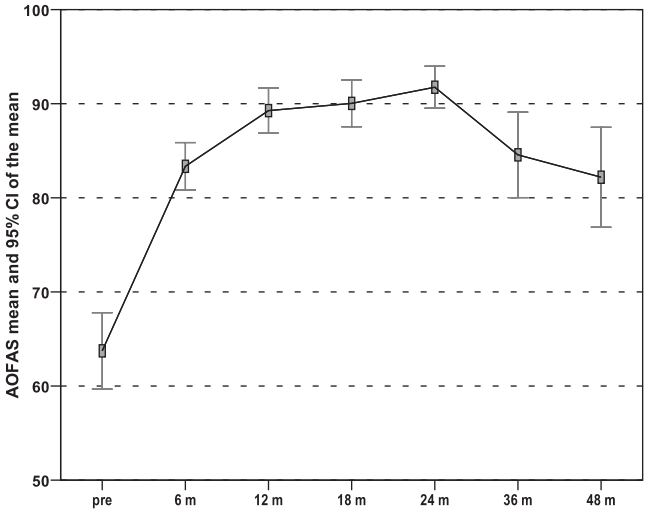

Figure 1. Pattern of the American Orthopaedic Foot and Ankle Society (AOFAS) score evaluated at established follow-ups up to 48 months.

up to a maximum of 91.76 ± 7.76 ($P < .0005$) at 24 months, with a percentage improvement of 76.75% ± 21.15% (Figure 1). Then, a decrease in the mean clinical score was reported, with a final value of 82.19 ± 17.04 ($P < .0005$) at 48 ± 6.1 months (in 42 patients), with a percentage improvement of 52.89% ± 45.76%.

Among the 36 patients (73%) playing sports (involved in soccer, basketball, skiing, and general fitness classes), the large majority (28 patients, 78%) were able to resume the previous sports level, while the remaining 8 patients (22%) resumed sports at a lower level or preferred to shift to a lower impact activity.

In the 20 patients who received MRI T2 mapping, the AOFAS score improved from 66.8 ± 14.5 preoperatively to 91.2 ± 8.3 at 24 months, 85.1 ± 16 at 36 months, and 83 ± 15 at 48.8 ± 7 months. The improvement from preoperative score to the final score at follow-up was statistically significant both overall and in the series of 20 patients who underwent MRI T2 mapping ($P < .0005$). Nevertheless, a significant decrease in the clinical score was observed between 24 and 36 months' follow-up ($P = .001$) and between 24 and 48 months' follow-up ($P < .005$).

Sex, traumatic lesion, depth of the lesion, site of injury, previous surgery, type of scaffold used, and the presence of impingement were not shown to influence the clinical outcome at any of the follow-ups evaluated. Age was shown to influence the clinical outcome only at 6 months, with the best improvement in younger patients ($r = –0.336$, $P = .018$).

The time between the occurrence of trauma and surgery has been shown to influence the clinical outcome at the latest follow-up. A long time having elapsed has adversely affected the clinical outcome at 36 months ($r = –0.318$, $P = .028$) and 48 months ($r = –0.0558$, $P = .025$).

The size of the lesion had an impact on the clinical score at 12, 18, and 24 months. In detail, lesions of larger sizes were associated with a lower clinical score at 12 months' ($r = –0.293$, $P = .04$), 18 months' ($r = –0.276$, $P = .05$), and 24 months' follow-up ($r = –0.343$, $P = .016$). This effect was lost at 48 months.

TABLE 1
Patients' Grades for Each MOCART Score Item at 24-Month Follow-up[a]

Parameter and Grade	Patients, %
Degree of filling of the osteochondral defect	
Complete	45
Hypertrophic	45
Incomplete >50%	10
Incomplete <50%	0
Exposure of subchondral bone	0
Integration to the border zone	
Complete	65
Incomplete	35
Surface of the repaired tissue	
Intact	40
Damaged <50%	40
Damaged >50%	20
Structure of the repaired tissue	
Homogeneous	15
Nonhomogeneous	85
Signal intensity of the repaired tissue (DPFSE)	
Isointense	70
Moderately hyperintense	30
Markedly hyperintense	0
Status of subchondral lamina	
Intact	10
Nonintact	90
Integrity of subchondral bone	
Intact	35
Nonintact	65
Presence of complications	
Joint effusion	5
Subchondral edema	60

[a]MOCART, magnetic resonance observation of cartilage repair tissue; DPFSE, delayed-phase fast spin echo.

Among the 20 patients who underwent MRI T2 mapping, the percentages of repartition of the patients for each MOCART score item are reported in Table 1, but no influence of any parameter was found on the clinical score at 48 months' follow-up. In 9 patients (45%), complete defect filling was observed; in 9 patients (45%), it was hypertrophic, while in 2 patients (10%), it was incomplete (less than 50% of the lesion volume). Integration to the border zone was complete in 13 patients (65%) and incomplete in 7 patients (35%). The repaired tissue surface was intact (type 3) in 8 patients (40%) and damaged (type 1, superior to 50% of the regenerated surface; or type 2, inferior to 50%) in 12 patients (60%). The reparative tissue was isointense (type 3) in 14 patients (70%) and moderately hyperintense (type 2) in 6 patients (30%). The subchondral lamina was intact in 2 patients (10%) and damaged in 18 patients (90%). The subchondral bone was intact in 7 patients (35%) and disrupted in 13 patients (65%). Joint effusion was evident in only 1 patient (5%), while 12 patients (60%) had subchondral edema.

T2 mapping performed on 20 patients at 24 months showed regenerated tissue with T2 values of 35 to

TABLE 2
T2 Values (24-Month Follow-up) and AOFAS Scores (24- and 48-Month Follow-up)[a]

Patient No.	T2 Value of 35-45 ms, %	T2 Value of >45 ms, %	T2 Value of <35 ms, %	Mean AOFAS at 24 mo	Mean AOFAS at 48 mo
1	92	5	1	100	90
2	92	8	0	100	100
3	91	6	3	100	100
4	88	9	0	100	65
5	83	15	2	100	100
6	62	38	0	100	96
7	93	0	7	97	100
8	92	5	3	97	87
9	80	18	2	96	100
10	85	7.5	7.5	90	73
11	58	38	4	90	78
12	60	40	0	90	85
13	73	21	6	88	86
14	50	42	0	87	82
15	52	38	10	87	51
16	90	6	4	87	100
17	91	9	0	87	78
18	85	13	2	79	70
19	96	1	3	75	66
20	50	0	50	75	58
Mean	78.1	16.5	5.1	91.2	83

[a]AOFAS, American Orthopaedic Foot and Ankle Society.

45 milliseconds, similar to hyaline cartilage, in a mean of 78% ± 16% of the repaired lesion area, ranging from 50% to 92% (Table 2). Clinical results at 48 months' follow-up showed a tendency to correlate with the percentage of tissue similar to hyaline cartilage according MRI T2 mapping (r = 0.497, P = .06).

While dividing patients in 2 groups according to the percentage of tissue rated as hyaline (T2 value of 35-45 ms), patients with more than 80% of hyaline regenerate gained an AOFAS score of 89 ± 16 at 48-month follow-up, while patients with less than 80% had an AOFAS score of 76 ± 18 (P = .007) (Figure 2).

A general deterioration of the clinical score was evident in the series between 24 and 48 months (P < .0005); nevertheless, the deterioration of the clinical score from 24 to 48 months was significantly reduced in patients with a higher presence of regenerated tissue, with a T2 value between 35 and 45 milliseconds (similar to hyaline tissue) (r = 0.546, P = .035). In particular, patients with less than 80% of this type of tissue showed a decrease of 23 ± 17 points from 24 to 48 months' follow-up, while patients with more than 80% showed a decrease of 6 ± 16 points (P = .07) (Figure 3).

A tendency toward a negative influence of the presence of tissue with <35 milliseconds (suggestive of fibrocartilage) on the AOFAS score was found at 48 months' follow-up (r = –0.488, P = .06) (Figure 4). The decrease in AOFAS score from 24- to 48-month follow-up instead showed a significant correlation with the percentage of fibrocartilage detected in the regenerated area (r = 0.516, P = .049). No effect of the presence of tissue with a T2 value >45 milliseconds (suggestive of tissue in the remodeling phase) was clinically evident at 48 months' follow-up (Figure 5).

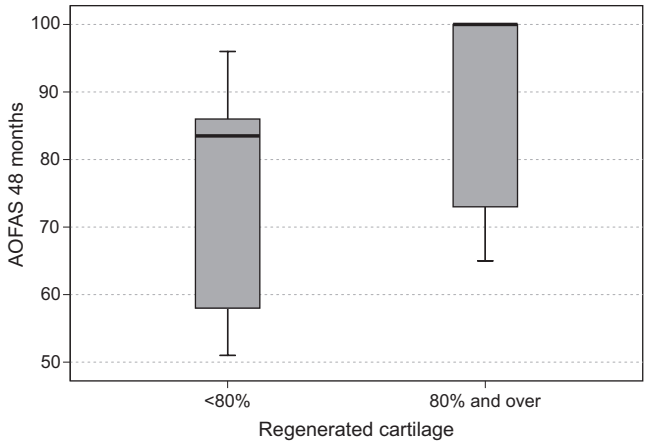

Figure 2. A significant relationship between the American Orthopaedic Foot and Ankle Society (AOFAS) score at 48 months' follow-up with the percentage of regenerated cartilage with hyaline features (T2 value of 35-45 ms) <80% and ≥80% is shown (P = .007).

DISCUSSION

Autologous chondrocyte implantation has shown the ability to regenerate reparative tissue with physical characteristics

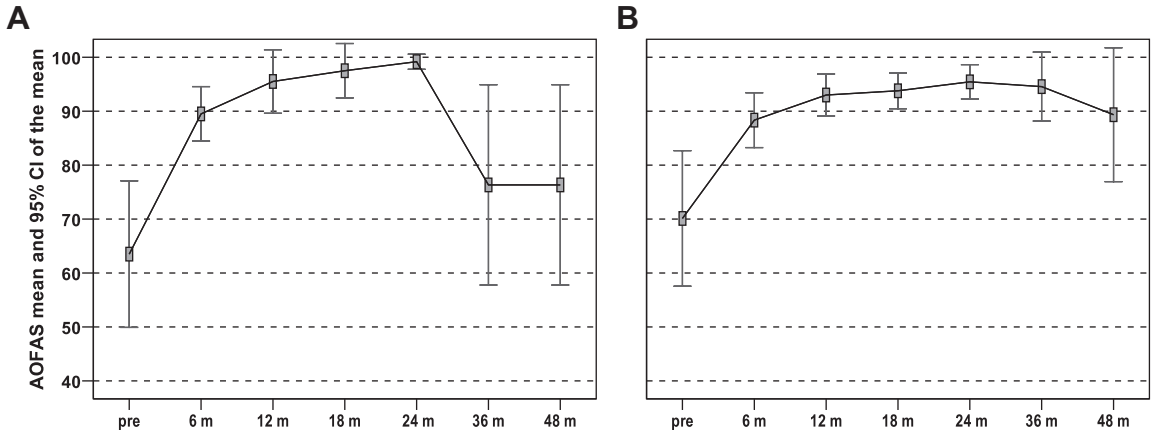

Figure 3. Deterioration of the clinical score from 24 to 48 months. In patients with a lower presence of regenerated tissue with a T2 value similar to hyaline tissue (A), the deterioration of the clinical score is significantly more evident with respect to the group with a higher percentage of hyaline tissue (B) (r = 0.546, P = .035).

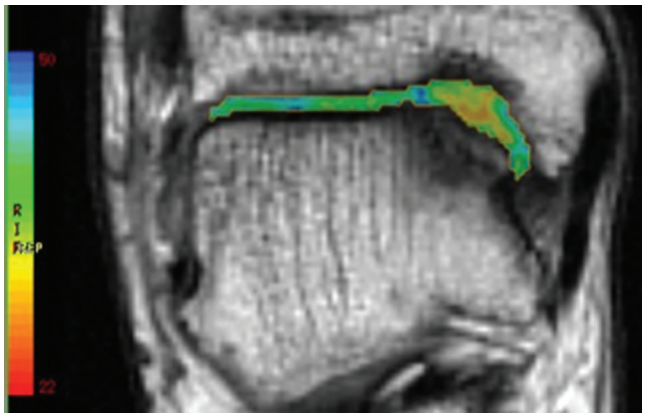

Figure 4. Coronal T2 mapping of an 18-year-old male patient with a clinical score of 75 shows a wide area of fibrocartilage (T2 value = 30 ms) and a small area similar to hyaline cartilage (T2 value = 43 ms) within the regenerated area.

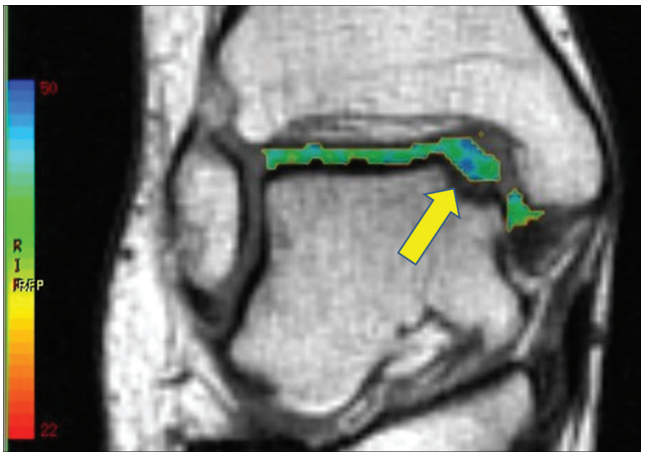

Figure 5. Coronal T2 mapping of a 21-year-old female patient with a clinical score of 100 shows regenerated tissue (T2 value = 45 ms) similar to that assumed to be indicative of healthy hyaline cartilage and a focal area with a T2 value of >45 milliseconds (arrow), which is the expression of tissue in the remodeling phase.

similar to those of healthy cartilage and is widely considered to be the gold standard in cartilage regeneration.[27] Furthermore, the use of a tissue-engineered biomaterial composed of autologous chondrocytes grown on a scaffold entirely made of HYAFF-11 enhanced the applicability of the technique, permitting a completely arthroscopic procedure in the knee and ankle.[16,21,22] Nevertheless, the need for 2 surgical operations and the high costs resulting from cell expansion are major drawbacks of this technique.

The arthroscopic "one-step" technique used in this study had extremely satisfactory clinical and MRI results and is free from the major disadvantages of techniques previously proposed, such as the high costs and the need for multiple surgeries.[4,10,15] In the present study, we proposed to verify the stability of the clinical results over time in patients operated by the one-step technique and to confirm the hypothesis that a high percentage of hyaline cartilage results in a higher clinical score, stable over time. The absence of a control group, the use of 2 different scaffolds for bone marrow–derived cell support, and the small number of MRI T2 mapping represent limitations of this study.

In this study, we noticed a decrease in the clinical score obtained from 24 to 48 months in the overall series of patients. Although this decrease was somewhat disappointing, the final clinical result was still satisfactory, and the final AOFAS score was still significantly improved from the initial score.

The MOCART score parameters did not correlate with the final clinical results: the signal intensity and the homogeneity of the regenerated tissue in DPFSE fat-saturated sequence, the finding of persisting lamina damage, subchondral bone disruption, and the presence of subchondral edema did not affect the final clinical result in this series. While at 2 years' follow-up, patients with an isointense

signal in the repaired tissue with respect to hyaline cartilage were able to obtain a median AOFAS score of 100, in contrast with patients with moderate signal hyperintensity who obtained a mean clinical score of 89 ($P = .05$), at final follow-up, this significance was lost. A negative relationship, evident at 2 years between the depths of the lesion, and the integrity of the surface of the regenerated tissue ($\tau = -.523$, $P = .007$), was also lost at this follow-up. These data were consistent with a previous study regarding ACI in the ankle, where at 5 years, no correlation was evident between MOCART parameters and the clinical score.[13]

The 9 patients with a defect filling rated as hypertrophic maintained a stable clinical result in 3 cases, while 6 showed a decrease with respect to clinical follow-up at 2 years, and in particular, 3 of them showed a poor result (inferior to baseline). These 3 patients gained the worst results of the series, and the hypertrophic regenerative tissue was associated with a damaged surface of the repaired tissue, nonhomogeneous signal, a moderate hyperintensity and subchondral edema, and nonintact subchondral lamina with alteration of the subchondral bone. Furthermore, lesion depth was 5 to 7 mm. Percentage of fibrocartilage in these cases ranged between 3% and 50%, while the presence of hyaline tissue ranged from 50% to 96%. None of them received a revision surgery to date.

The MRI T2-mapping evaluation was performed at 24 months, and the clinical results obtained at this time showed that patients with more than 80% of regenerated tissue, discriminated by T2 mapping as hyaline, showed a significantly better clinical outcome at 48 months in comparison with patients with less than 80% of hyaline cartilage ($P = .007$).

Although patients need to be followed over time up to the long term to evaluate if further deterioration of the clinical score occurs, the one-step technique was effective in regenerating tissue with hyaline features in OLTs. The presence of foci of fibrocartilage strongly affected the clinical outcome and the stability of the results over time, this correlation is not limited to just the one-step technique and has been noticed in 2 different series of comparable patients operated with the open and arthroscopic technique.[5,13] This finding is suggestive that both ACI and the one-step technique result in a similar reparative tissue constituted in a large part of cartilage with hyaline features and also with the presence of small areas of fibrocartilage and of cartilage in the remodeling phase. An important consideration that emerged from this study is that the patient who has the best possibility of maintaining an excellent clinical score in the midterm is the patient with a high percentage of regenerated tissue similar to hyaline cartilage (T2 value of 35-45 ms) and a low percentage of fibrocartilage (T2 value of <35 ms). The midterm outcome showed no relationship with the percentage of tissue in the remodeling phase (T2 value of >45 ms). Although no correlations were evident at this follow-up with MOCART parameters, while studying the patients in detail, it is evident that patients with an unsatisfactory outcome still presented 1 or more altered MOCART parameters.

In conclusion, these findings show that one-step repair of OLTs had good clinical results after 4 years of follow-up, although there was some decline in the AOFAS scores between 24 and 48 months postoperatively. Nevertheless, the presence of regenerated hyaline in nature, although a necessary condition to maintain a stable and durable result over time, is not a sufficient condition. Other parameters such as the morphological characteristics of regenerated tissue are needed while predicting the outcome.

REFERENCES

1. Aigner J, Tegeler J, Hutzler P, et al. Cartilage tissue engineering with novel nonwoven structured biomaterial based on hyaluronic acid benzyl ester. *J Biomed Mater Res*. 1998;42:172-181.
2. Angermann P, Jensen P. Osteochondritis dissecans of the talus: long-term results of surgical treatment. *Foot Ankle*. 1989;10:161-163.
3. Basad E, Ishaque B, Bachmann G, Sturz H, Steinmeyer J. Matrix-induced autologous chondrocyte implantation versus microfracture in the treatment of cartilage defects of the knee: a 2-year randomised study. *Knee Surg Sports Traumatol Arthrosc*. 2010;18(4):519-527.
4. Battaglia M, Rimondi E, Monti C, et al. Validity of T2 mapping in characterization of the regeneration tissue by bone marrow derived cell transplantation in osteochondral lesions of the ankle. *Eur J Radiol*. 2011;80(2):e132-e139.
5. Battaglia M, Vannini F, Buda R, et al. Arthroscopic autologous chondrocyte implantation in osteochondral lesions of the talus: mid-term T2-mapping MRI evaluation. *Knee Surg Sports Traumatol Arthrosc*. 2011;19(8):1376-1384.
6. Bosien WR, Staples OS, Russell SW. Residual disability following acute ankle sprains. *J Bone Joint Surg Am*. 1955;37:1237-1243.
7. Brun P, Abatangelo G, Radice M, et al. Chondrocyte aggregation and reorganization into three-dimensional scaffolds. *J Biomed Mater Res*. 1999;46:337-346.
8. Buckwalter JA, Lohmander S. Operative treatment of osteoarthrosis: current concepts review. *J Bone Joint Surg Am*. 1994;76:1405-1418.
9. Buckwalter JA, Mow VC, Ratcliffe A. Restoration of injured or degenerated articular cartilage. *J Am Acad Orthop Surg*. 1994;2:192-201.
10. Buda R, Vannini F, Cavallo M, Grigolo B, Cenacchi A, Giannini S. Osteochondral lesions of the knee: a new one-step repair technique with bone-marrow-derived cells. *J Bone Joint Surg Am*. 2010;92 Suppl 2:2-11.
11. Choi YS, Potter HG, Chun TJ. MR imaging of cartilage repair in the knee and ankle. *Radiographics*. 2008;28(4):1043-1059.
12. Franchini M, Dupplicato P, Ferro I, De Gironcoli M, Aldegheri R. Efficacy of platelet gel in reconstructive bone surgery. *Orthopedics*. 2005;28:161-163.
13. Giannini S, Battaglia M, Buda R, Cavallo M, Ruffilli A, Vannini F. Surgical treatment of osteochondral lesions of the talus by open-field autologous chondrocyte implantation: a 10-year follow-up clinical and magnetic resonance imaging T2-mapping evaluation. *Am J Sports Med*. 2009;37 Suppl 1:112S-118S.
14. Giannini S, Buda R, Faldini C, et al. Surgical treatment of osteochondral lesions of the talus in young active patients. *J Bone Joint Surg Am*. 2005;87(Suppl 2):28-41.
15. Giannini S, Buda R, Vannini F, Cavallo M, Grigolo B. One-step bone marrow-derived cell transplantation in talar osteochondral lesions. *Clin Orthop Relat Res*. 2009;467(12):3307-3320.
16. Giannini S, Buda R, Vannini F, Di Caprio F, Grigolo B. Arthroscopic autologous chondrocyte implantation in osteochondral lesions of the talus: surgical technique and results. *Am J Sports Med*. 2008;36(5):873-880.
17. Gold GE, McCauley TR, Gray ML, Disler DG. What's new in cartilage? *Radiographics*. 2003;23(5):1227-1242.
18. Hunziker EB. Articular cartilage repair: basic science and clinical progress. A review of the current status and prospects. *Osteoarthritis Cartilage*. 2002;10:432-463.

19. Kitaoka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. *Foot Ankle Int*. 1994;15:349-353.
20. Lucarelli E, Beccheroni A, Donati D, et al. Platelet-derived growth factors enhance proliferation of human stromal stem cells. *Biomaterials*. 2003;24:3095-3100.
21. Marcacci M, Berruto M, Brocchetta D, et al. Articular cartilage engineering with Hyalograft C: 3-year clinical results. *Clin Orthop Relat Res*. 2005;435:96-105.
22. Marcacci M, Kon E, Zaffagnini S, et al. Arthroscopic second generation autologous chondrocyte implantation. *Knee Surg Sports Traumatol Arthrosc*. 2007;15:610-619.
23. Marlovits S, Singer P, Zeller P, et al. Magnetic resonance observation of cartilage repair tissue (MOCART) for the evaluation of autologous chondrocyte transplantation: determination of interobserver variability and correlation to clinical outcome after 2 years. *Eur J Radiol*. 2006;57(1):16-23.
24. Mazzucco L, Medici D, Serra M, et al. The use of autologous platelet gel to treat difficult-to-heal wounds: a pilot study. *Transfusion*. 2004;44:1013-1018.
25. Mosher TJ, Dardzinski BJ. Cartilage MRI T2 relaxation time mapping: overview and applications. *Semin Musculoskelet Radiol*. 2004; 8(4):355-368.
26. O'Driscoll S. The healing and regeneration of articular cartilage: current concepts review. *J Bone Joint Surg Am*. 1998;80:1795-1812.
27. Oreffo RO, Cooper C, Mason C, Clements M. Mesenchymal stem cells: lineage, plasticity, and skeletal therapeutic potential. *Stem Cell Rev*. 2005;1:169-178.
28. Pritsch M, Horoshovsky H, Farine I. Arthroscopic treatment of the osteochondral lesion of the talus. *J Bone Joint Surg Am*. 1986;68:862-865.
29. Ragusa R, Faggian G, Rungatscher A, Cugola D, Marcon A, Mazzucco A. Use of gelatin powder added to rifamycin versus bone wax in sternal wound hemostasis after cardiac surgery. *Interact Cardiovasc Thorac Surg*. 2007;6:52-55.
30. Schenck RC Jr, Goodnight JM. Osteochondritis dissecans. *J Bone Joint Surg Am*. 1996;78:439-456.
31. Xia Y. Magic-angle effect in magnetic resonance imaging of articular cartilage: a review. *Invest Radiol*. 2000;35(10):602-621.