Concomitant Meniscal Allograft Transplantation and Autologous Chondrocyte Implantation: Minimum 2-Year Follow-up

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Am. J. Sports Med. 2007; 35; 1459 originally published online Apr 13, 2007;
DOI: 10.1177/0363546507301257

Concomitant Meniscal Allograft Transplantation and Autologous Chondrocyte Implantation

Minimum 2-Year Follow-up

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Background: Although recent studies have shown intermediate-term success of both meniscal allograft transplantation (MAT) and autologous chondrocyte implantation (ACI) performed separately, there have been no peer-reviewed studies focused prospectively on the combined procedure. By potentially reestablishing a compartment contact area closer to normal, MAT may allow a more optimal environment for ACI by reducing stress (stress = force/unit area). On the other hand, the literature suggests that MAT alone in the presence of extensive chondrosis performs poorly. Restoring the articular cartilage may allow the MAT to perform more similarly to series with nearly normal articular cartilage.

Hypothesis: Performed concomitantly, ACI and MAT will result in significant improvements in knee function as measured by functional scoring scales and visual analog pain scales.

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

Methods: Preoperative and postoperative comparisons of Browne modified Cincinnati functional levels, Lysholm, visual analog rest and maximum pain, and satisfaction scores were recorded. Thirty-six total procedures were performed between 1999 and 2004.

Results: Of the 36 patients entering the series, 29 had >2-year evaluation and scores. Four patients were recorded as failures before the 2-year follow-up and required revision surgery. Three patients were lost to follow-up. A total of 21 medial and 8 lateral MAT/femoral condyle ACIs were performed. Sixteen of 29 patients had concomitant procedures performed, including tibial tuberosity osteotomy, anterior cruciate ligament reconstruction, and high tibial osteotomy. Patients demonstrated statistically significant improvement in the standardized outcome surveys, visual analog pain, and satisfaction scores. The Browne Cincinnati (Patient and Clinician, respectively) showed an improvement from 3.9 (standard deviation [SD], 1.5) and 4.0 (SD, 1.4) preoperatively to 6.3 (SD, 1.9) postoperatively for both. The Lysholm also showed an improvement from 57.7 (SD, 16.2) preoperatively to 77.7 (SD, 19.3) postoperatively. There were no significant differences noted in any of the subgroups (medial vs lateral, isolated vs concomitant, or unipolar vs bipolar).

Conclusion: At a minimum of 2-year follow-up, MAT in combination with ACI demonstrates improvement in both symptoms and knee function. However, the improvements are less than literature-reported outcomes of either procedure performed in isolation.

Keywords: meniscus; meniscal transplant; autologous chondrocyte implantation; cartilage

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One or more authors has declared a potential conflict of interest: research or institutional support has been received by various companies, including Genzyme Biosurgery, Regeneration Technologies, Stryker, Orthofix, Depuy, and Mitek; royalties have been received from Stryker, Orthofix, Depuy, and Mitek; stock options are held from Regeneration Technologies, Osteobiologics, and Bionicare; and one or more authors is a consultant for or employee of Johnson & Johnson Companies, Stryker, Orthofix, and Bionicare.

The American Journal of Sports Medicine, Vol. 35, No. 9
DOI: 10.1177/0363546507301257

Clinical applications of cartilage restoration are rapidly evolving. As such, some parameters of treatment have been adopted empirically. These empiric assumptions need reassessment on a regular basis to ensure that they meet the rigors of evidence-based medicine. Building on earlier cartilage restoration clinical series, it is now generally accepted that knee articular cartilage restoration procedures require an optimization of the knee biomechanical environment to allow the restoration to succeed to its fullest potential. Thus, articular cartilage restoration algorithms typically suggest[12,16] (1) normal alignment or concomitant normalization, (2) stable ligament status or concomitant reconstruction, and (3) intact meniscal function. Likewise, meniscal cartilage restoration also requires an optimal environment, including alignment, stability, and nearly normal articular cartilage (International Cartilage Repair Society [ICRS] grade 2 or less chondrosis).[9,10,16,31] When patients are assessed for cartilage restoration, many have both meniscal and articular cartilage lesions in the same (ipsilateral) compartment. Although an empiric approach would suggest treating these concomitant defects with concomitant meniscal and articular cartilage restoration,[15] prospective patient series of these 2 procedures performed concomitantly were not discovered in standard Web-based searches of the literature using PubMed. Review of non-peer-reviewed periodicals revealed that Gersoff[18] previously reported on 19 patients with concomitant autologous chondrocyte implantation (ACI) and meniscal allograft transplantation (MAT) with an average follow-up of 24.7 months; the Cincinnati knee scores improved from 2.3 to 7.2, but standard deviation and statistical analysis were not reported. Four patients had arthrofibrosis and required surgical debridement. Although Gillogly[19] reported a series of ACI patients who had a MAT (no subset analysis was performed) and Cole et al[10] reported a MAT series that included 1 patient who had an ACI, the combination of MAT and ACI was not the focus of those articles. The current clinical prospective series investigates the outcomes of patients undergoing concomitant meniscal and articular cartilage restoration using the ACI technique of Brittberg et al.[5]

The rationale to combine meniscal and chondral surgery is based on the literature concerning each of these tissues separately. It is well established that most (80% to 90%) meniscal injuries are not amenable to repair, which leads to a partial meniscectomy (a form of functional meniscectomy, as Lee et al[23] demonstrated in a cadaveric study with serial excision of meniscal tissue). Numerous authors have shown the predictable articular cartilage degeneration after meniscectomy,[1,2,13,23,40,42] which is due in part to multiple factors, including increased stress (force per unit area), loss of shock absorption, decreased joint lubrication, decreased joint congruity, and possibly altered joint nutrition. With an increased understanding of meniscal function, MAT has been reported for the treatment of the symptomatic knee after meniscectomy.[10,43] While classic studies showed degeneration of the knee after meniscectomy, recent studies in the literature suggest the possibility of a chondroprotective function of MAT.[20,36,44]

During a somewhat similar time frame, articular cartilage restoration has evolved systematically since the introduction of ACI by Brittberg et al in 1994.[5] Regardless of the articular cartilage technique, standard cartilage restoration algorithms require appropriate ligamentous stability, bony alignment, intact meniscal function, and near-normal range of motion and muscle strength. The current study evaluated patients with ≥ grade 3 chondrosis (ICRS grading scale) and a functional meniscectomy treated with a concomitant ACI and MAT.

MATERIALS AND METHODS

Patient Evaluation

After institutional review board approval was obtained for the study of outcomes after knee intervention, all patients enrolled underwent an informed consent process. Patients who underwent concomitant ipsilateral ACI and MAT were prospectively observed. Inclusion criteria were persistent pain after documented meniscectomy to within 3 mm of the posterior horn or more and ipsilateral focal chondrosis >2 cm^2 in the area with ≥ grade 3 (ICRS grading system) chondrosis per arthroscopic evaluation. The senior author elected to treat patients using a standard cartilage restoration algorithm (Jack Farr, MD, unpublished data, 2005) that calls for normalization of the knee before or at the time of cartilage restoration. Thus, patients with concomitant procedures to correct alignment and stability were also included in the study. As a result, all patients were within 3° of neutral knee alignment on the affected side and had intact ligamentous function either established before or concomitant with the ACI/MAT surgery (eg, anterior cruciate ligament [ACL] reconstruction for ACL deficiency or high tibial valgus osteotomy for a varus knee with medial injuries). From a data analysis standpoint, it would have been advantageous to “normalize” the stability and alignment of the knee before the MAT/ACI procedure, but in the interest of the patient (1 vs 2 major surgeries, anesthesia, rehabilitation, crutch use, and time off school or work) and the knee (more separate surgeries on the knee could potentially increase the risk of scar formation and major strength deficits to overcome), alignment and stabilizing procedures were performed concomitantly with MAT and ACI.

All patients had a thorough history and physical examination performed to exclude other sources of their pain and dysfunction. During the initial evaluation, plain radiographs, including standing anteroposterior, lateral, Merchant view, and Rosenberg 45°-flexion weightbearing posterior anterior views,[38] were obtained. Patients who had an examination finding consistent with coronal tibiofemoral malalignment underwent weightbearing hip-to-ankle mechanical axis views. Malalignment of >3° was treated with a corrective osteotomy. Alignment was corrected to near neutral, with the weightbearing line near the tibial spine of the contralateral compartment.

The evaluation also included a review of previous records, including radiographs, magnetic resonance imaging (MRI), operative reports, arthroscopy pictures, and physician notes. A staging arthroscopy was performed on all patients to delineate the ICRS grade, surface area (lesion dimensions) of the lesion, and ICRS region of chondrosis, as well as the extent of meniscal deficiency. Patients with advanced chondrosis, as evidenced by flattening of the articular surface or extensive osteophyte formation, were excluded from the study.

Preoperative Planning and Operative Technique

All transplanted menisci were measured and sized from radiographs via the technique described by Pollard et al.[35] The senior surgeon sized all menisci. In all cases, fresh-frozen nonirradiated menisci were used. All medial and lateral menisci were transplanted using the "slot technique," which has been previously described by Cole et al.[11] The meniscus remnant was debrided arthroscopically, leaving a stable 2-mm peripheral rim that was treated with perimeniscal synovial abrasion and meniscal trephination with a wire. A minimal notchplasty was performed to improve visualization of the posterior horn attachment site and allow smooth graft passage. A miniarthrotomy in line with the meniscal horn attachment sites was performed in all cases to allow meniscal allograft passage. The soft tissue portion of the MAT was secured with a traditional inside-out technique using No. 2-0 nonabsorbable sutures. Typically, 8 to 10 vertical mattress sutures were needed to provide stable fixation. Both medial and lateral menisci were transplanted using a bone bridge in the slot technique. The bone bridge was secured by passing nonabsorbable sutures through the bone plug and out through the anterior cortex of the tibia (hole formed using an ACL jig and wire) in 11 of the patients, while an interference fixation was used to secure the bone bridge in the bone slot (as described by Farr and Cole[14]) in 18 patients.

The articular cartilage lesions were documented at the time of the staging arthroscopy as to region, grade, and dimensions. The biopsy specimen for the ACI was harvested from the notch area, with care taken to avoid taking a biopsy sample adjacent to a lesion. Cells were cultured at Genzyme Biosurgery using the Carticel process (Genzyme Biosurgery, Cambridge, Mass) and were available for implantation the day of the definitive surgery. To avoid damage to the periosteal patch, the ACI portion of the procedure was performed after the meniscal transplant was sutured into position. Autologous chondrocyte implantation was performed using the technique of Brittberg et al[5]; typically, an extension of the MAT incision was required for visualization. The site was prepared by debriding the articular cartilage lesion, leaving a well-shouldered lesion with sharp vertical walls, and removing the layer of calcified cartilage and any intralesional osteophytes. The defect area was templated, and the template was then used to harvest the appropriately sized and shaped periosteal patch (typically obtained from the area of the medial proximal tibial just distal to the pes anserine attachment). After complete hemostasis was achieved with the tourniquet deflated, the periosteal patch was secured over the defect with the cambium layer toward bone, using simple interrupted 6-0 Vicryl sutures (Ethicon Inc, Somerville, NJ) at 3-mm intervals, leaving an opening for cell injection. An injection of sterile saline was performed to ensure a watertight seal, which was then further augmented with fibrin glue. The cultured chondrocytes were then injected under the patch to fill the defect. The injection site opening in the patch was then closed with 6-0 Vicryl suture and sealed with fibrin glue.[5-7]

Postoperatively, the patients wore a hinged knee brace and were nonweightbearing for the first 6 weeks. During the first 2 weeks, range of motion (ROM) was limited to 0° to 30° with the hinged brace for protection, while the allowed motion was 0° to 60° in a continuous passive motion (CPM) machine, which was used a minimum of 8 hours per day within this range. Further flexion during this time period was discouraged to minimize anterior-posterior MAT graft motion. From weeks 2 to 4, CPM motion was increased to 0° to 90°, with the brace opened to 0° to 60°, again for protection. After 4 weeks, full ROM was allowed out of the brace, which was still used for protection when ambulating. After 6 weeks, gradual progression to full weightbearing was allowed if adequate lower extremity strength and control were demonstrated and there was no limp. Full ROM was the goal by 8 weeks. Full release to functional progression to activities was allowed at 9 to 12 months, using a highly individualized program dependent on the extent of the surgery and the patient's goals.

Outcomes Assessment

Forty-eight patients received an ACI and MAT in the same compartment in a single session from May 1999 to February 2006. Of these 48 patients, 36 patients/knees were a minimum of 24 months past surgery; however, 3 were lost to follow-up, and 4 patients had failures before the 24-month data acquisition follow-up point, resulting in the study group of 29 patients. For comparison, during the same time frame, the senior author (J.F.) performed ACI on 214 patients and MAT on 114 patients. The senior orthopaedic surgeon (J.F.) performed all surgeries, as well as preoperative and postoperative evaluations. Data collection was performed by research staff. Patient evaluations were performed preoperatively, 6 months postoperatively, 1 year postoperatively, and yearly thereafter using the Browne modified Clinician Cincinnati (objective),[8,32] Browne modified Patient Cincinnati (subjective),[8,32] Lysholm,[24] visual analog scale for rest and maximum pain, and satisfaction scores. Treatment failures or complications were recorded and appropriately treated. Statistical analysis was performed using both parametric and nonparametric testing methods using CSS: Statistica, Version 6.0 (StatSoft Inc, Tulsa, Okla). All groups and subgroups were first analyzed by the Student t test. Next, the overall group was analyzed using the Wilcoxon matched-pair test and the subgroups by the Mann-Whitney U test. For this study, $P < .05$ was deemed to be statistically significant.

RESULTS

Thirty-six patients with combined MATs and ACIs met the requirement for initial inclusion. Four patients had failures

TABLE 1
Average Preoperative and Follow-up Scores for All Patients[a]

Outcome	Preoperative Mean Score ± SD (Range)	Postoperative Mean Score ± SD (Range)	*t* Test *P* Value	Wilcoxon Matched-Pair Test *P* Value
MDC	3.96 ± 1.4 (1-7)	6.29 ± 1.9 (2-9)	<.001	<.001
PTC	3.93 ± 1.5 (2-8)	6.29 ± 1.9 (2-9)	<.001	<.001
Lysholm	57.66 ± 16.2 (27-87)	77.72 ± 19.3 (25-100)	<.001	<.001
Rest pain	2.52 ± 2.1 (0-7)	1.25 ± 2.3 (0-10)	.036	.035
Maximum pain	7.62 ± 1.8 (3-10)	5.11 ± 2.8 (0-10)	<.001	<.001
Satisfaction	1.10 ± 1.2 (0-5)	3.13 ± 2.3 (0-5)	<.001	<.012

[a]SD, standard deviation; MDC, Modified Cincinnati Knee Score; PTC, Patient Cincinnati Knee Score.

before 2 years, and these patients were excluded from the scoring scale because they were revised to alternative procedures before the minimum 2-years' follow-up data were acquired. However, these patients were included in the failure rate calculation for the procedure. Three patients were lost to follow-up, leaving a total of 29 patients (23 men and 6 women) to be scored in this study. The average follow-up time was 4.5 ± 1.3 years. The average age for the patients was 36.9 ± 9.1 years (range, 16.1-52.1 years). A total of 21 (72%) medial compartment and 8 (28%) lateral compartment meniscal transplants with ACI were performed. Four patients received treatment for bipolar lesions involving the ipsilateral compartment femoral condyle and tibial plateau. This involved ACI to both the femoral and tibial lesions in addition to the meniscal transplant. Thirteen procedures were done in isolation; 16 were done with concomitant procedures. Concomitant procedures were performed to create the optimal environment for the MAT and ACI. In 6 medial compartment patients, a high tibial valgus osteotomy was performed to optimally place the patient's alignment into 2° to 3° of valgus. One patient had a tibial tubercle medialization to address static chronic lateral patellar subluxation without cartilage damage. One patient had a tibial tubercle osteotomy for visualization (very posterior femoral condyle chondrosis), in which the tubercle was reattached in the original position; this patient also had an ACL reconstruction for ACL patholaxity. Seven additional patients had an ACL reconstruction for ligament patholaxity at the time of ACI and MAT. One patient had a concomitant anteriomedialization to address patellofemoral pain and lateral patellar tilt/lateral patellar compression.

In all patients, the size of the implanted ACI was measured and documented. For the medial meniscal transplant group, the average size of the ACI-treated lesion within the ipsilateral compartment was 6.36 cm^2 (range, 1.5-12.1 cm^2; standard deviation [SD], 3.26). In cases where lesions outside the medial MAT were implanted (eg, a trochlear lesion), the average lesion size of the regions outside of the studied compartment was 4.77 cm^2 (range, 2.6-8.75 cm^2; SD, 2.06). For the lateral meniscus group, the average size of the ACI-treated lesion within the ipsilateral compartment was 5.35 cm^2 (range, 2.4-9.3 cm^2; SD, 1.8). The lesions outside of the studied lateral compartment measured 2.68 cm^2 (range, 1.9-3.6 cm^2; SD, 0.57). Overall, there were statistically significant ($P < .05$) improvements in the Browne modified Cincinnati (Patient and Clinician), Lysholm, visual analog rest and maximum pain, and satisfaction scores from preoperative evaluation to most recent follow-up (Table 1). The mean Browne modified Cincinnati score improved from an initial preoperative 3.96 (SD, 1.38) to 6.29 (SD, 1.87) at final follow-up. The mean patient modified Cincinnati score improved from 3.93 (SD, 1.53) to 6.29 (SD, 1.87) at the most recent follow-up (Figure 1). Lysholm knee scores showed improvement from an initial 57.7 (SD, 16.2) to 77.7 (SD, 19.3) at the most recent follow-up (Figure 2). Rest pain and maximum pain score decreased significantly, from 2.52 (SD, 2.14) and 7.62 (SD, 1.78) to 1.25 (SD, 2.30) and 5.12 (SD, 2.83), respectively. Overall satisfaction scores increased from a preoperative 1.10 (SD, 1.21) to a final follow-up score of 3.13 (SD, 2.32) (Figure 1).

Medial Versus Lateral Procedures

Although both the medial and lateral groups showed significant improvements in Browne modified Cincinnati (Patient and Clinician), Lysholm, visual analog rest and maximum pain, and satisfaction scores, there was no statistical difference between the 2 subgroups, with the exception of the Lysholm score (Table 2). The medial group improved an average of 27.29 points, while the lateral group only improved 1.13 points. However, the lateral group had much higher preoperative Lysholm scores versus the medial group (68.38 vs 53.6 [Mann-Whitney U P = .036]). In all other scores, there was no statistical difference between the lateral and medial subgroups. There was a trend toward higher final follow-up maximum pain in the lateral group compared with the medial group with a Mann Whitney U P value of .061.

Bipolar Versus Unipolar Lesions

There were a total of 6 patients with bipolar lesions; however, 1 of these patients was lost to follow-up, and 1 had a failure before the 2-year follow-up and received a total knee arthroplasty (see failure section below). Thus, in our study group, 4 knees had treatment with ACI on both the femoral condyle and tibial plateau of the involved compartment. The other 25 knees had treatment for a unipolar femoral condyle lesion only. As it is not possible to statistically analyze the

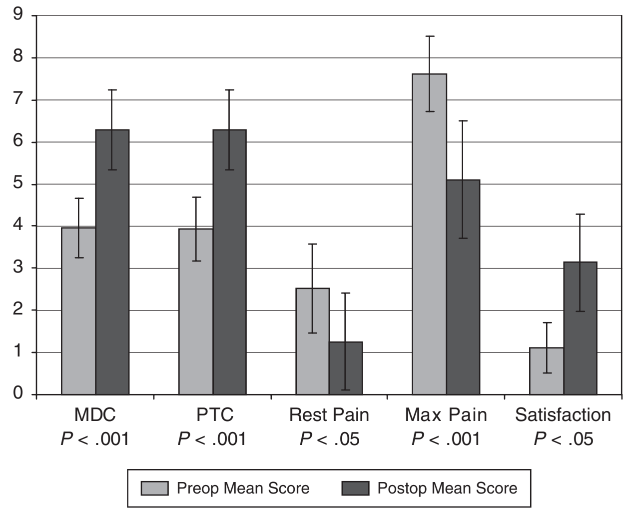

Figure 1. Comparison of preoperative scores with most recent follow-up. MDC, Modified Cincinnati Knee Score; PTC, Patient Cincinnati Knee Score.

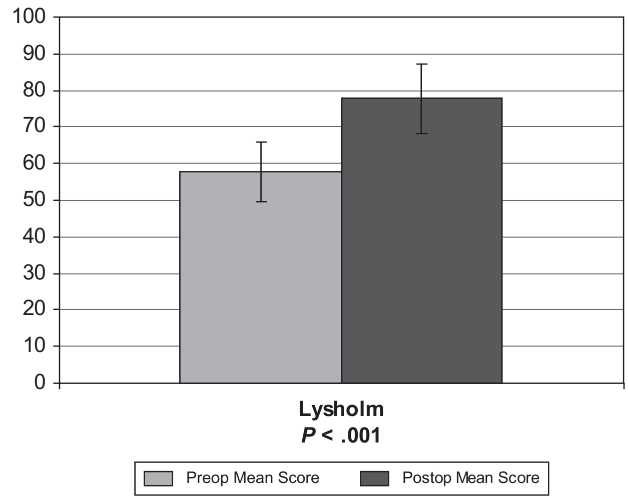

Figure 2. Comparison of preoperative Lysholm scores with most recent follow-up.

small group of patients with bipolar lesions, their individual data are as follows: patient 1 had a preoperative Lysholm score of 87 and a postoperative score of 71, along with satisfaction change from a 3 to a 4; patient 2 had a preoperative Lysholm score of 48 and a postoperative score of 31, while the satisfaction stayed the same at 1; patient 3 had a preoperative Lysholm score of 35 and a postoperative score of 83, along with satisfaction change from 1 to 3; and patient 4 had a preoperative Lysholm score of 58 and a postoperative score of 84, while the satisfaction went from 1 to 3. Nonparametric testing using the Mann-Whitney *U* test revealed no statistical significance between the 2 subgroups (Table 3). This must be interpreted in light of the small group size and thus inadequate power to show any statistical difference.

TABLE 2
Comparison of Outcome Scores Between Patients With Medial (n = 21) and Lateral (n = 8) Lesions[a]

Outcome	Medial Mean Score	Lateral Mean Score	*t* Test *P* Value	Mann-Whitney *U P* Value
Δ MDC	2.81	1.60	ns	ns
Δ PTC	2.75	1.60	ns	ns
Δ Lysholm	27.29	1.13	.008	.010
Δ Rest pain	–1.15	–1.50	ns	ns
Δ Maximum pain	–3.20	–0.50	.041	.061
Δ Satisfaction	2.27	1.00	ns	ns

[a]Δ, change; MDC, Modified Cincinnati Knee Score; PTC, Patient Cincinnati Knee Score; ns, not significant.

TABLE 3
Comparison of Change in Outcome Scores of Patients With Unipolar (n = 25) and Bipolar (n = 4) Lesions[a]

Outcome	Bipolar Mean Score	Nonbipolar Mean Score	*t* Test *P* Value	Mann-Whitney *U P* Value
Δ MDC	2.00	2.61	ns	ns
Δ PTC	0.67	2.78	ns	ns
Δ Lysholm	10.25	21.64	ns	ns
Δ Rest pain	0.75	–1.58	ns	ns
Δ Maximum pain	0.00	–2.83	ns	ns
Δ Satisfaction	1.00	2.08	ns	ns

[a]Δ, change; MDC, Modified Cincinnati Knee Score; PTC, Patient Cincinnati Knee Score; ns, not significant.

TABLE 4
Change in Outcome Scores Between Patients With Isolated Procedures (n = 13) Versus Those With Concomitant Procedures (n = 16)[a]

Variable	Isolated Mean Score	Concomitant Mean Score	*t* Test *P* Value	Mann-Whitney *U P* Value
Δ MDC	2.64	2.40	ns	ns
Δ PTC	2.91	2.00	ns	ns
Δ Lysholm	15.94	25.15	ns	ns
Δ Rest pain	–0.93	–1.62	ns	ns
Δ Maximum pain	–2.47	–2.38	ns	ns
Δ Satisfaction	1.67	2.33	ns	ns

[a]Δ, change; MDC, Modified Cincinnati Knee Score; PTC, Patient Cincinnati Knee Score; ns, not significant.

Procedure Performed in Isolation Versus Concomitant Procedures

Thirteen procedures were done in isolation; 16 were done with concomitant procedures as reported above. Statistical comparison of these groups using the Mann-Whitney *U* test revealed no statistical difference (Table 4) in any of the scoring scales in comparing the 2 groups, once again acknowledging the inherent statistical limitations with such small group sizes.

Failures

Four patients had failures and required surgical intervention before the 2-year mark; they were excluded from statistical analysis secondary to failure to meet the study inclusion criteria. This exclusion of failures from further analysis is based on the same type of failure exclusion from data interpretation used in the recent series of MAT reported by Cole et al[10] in this journal. The first patient was found to have delamination of ACI at 13 months after surgery. This patient required a revision procedure that involved another ACI procedure, which was stable at the 2-year follow-up. The second patient had failure at 11 months after surgery of both the meniscal transplantation and the ACI. This patient was originally referred to us seeking an alternative to total knee arthroplasty. After failure of the index procedure, the patient underwent a total knee arthroplasty. The third patient had a failure of the lateral meniscal transplant at 17 months after surgery and had revision lateral meniscal transplantation. At most recent follow-up, the lateral meniscus was satisfactory. The final failure was a patient who was originally treated elsewhere for a discoid lateral meniscus as a young child and then treated with ACI/MAT at 23 years of age. At 23 months after surgery, the patient had a complete meniscectomy secondary to an atypical anterior horn degenerative tear of the transplanted lateral meniscus. The patient is currently awaiting repeat lateral MAT; the ACI-treated area healed with an ICRS score of 9 of 12.

Additional Procedures

On average, patients had 0.96 (SD, 0.94) procedures performed after the index procedure (Figure 3). This does not include the 4 failures described above. To fully acknowledge all additional procedures, the failure group contributed 7 additional procedures. One patient had 1 additional surgery, while the other 3 patients had 2 additional procedures. Of the 29 patients, 9 (31%) had no additional procedures, 15 (52%) had 1 additional procedure, 3 (10%) had 2 additional procedures, 1 (3%) had 3 additional procedures, and 1 (3%) had 4 additional procedures. Most often, the additional surgery involved a trimming of a degenerative central rim of the implanted menisci or trimming of periosteal overgrowth of the ACI. The patients with 3 and 4 additional procedures were operated on by outside surgeons, and information regarding the need for additional surgery or the details of the surgeries are unknown.

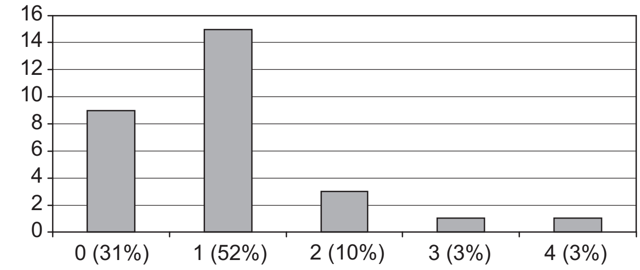

Figure 3. Number of postoperative procedures.

DISCUSSION

Meniscal tissue has many important functions, including joint load transmission, joint lubrication, joint congruity, and joint nutrition—that is, chondroprotection. Many studies have shown that even a small-appearing posterior horn meniscal resection can result in a functional meniscectomy.[1,2,23] This leads to increased peak stresses in the knee joint. Over time, the lack of an intact meniscus leads to predictable chondrosis.[1,13,42]

Over the past 15 years, there have been numerous studies documenting the success of isolated MAT and isolated ACI. The first study on isolated meniscal transplantation was performed by Milachowski et al[27] in 1984 and reported in 1989. Of the 22 allograft transplantations performed, an 86% success rate was seen at a mean 14-month follow-up. Garrett and Steensen[17] published the first American experience, reporting an 81% success rate in 43 patients with 2- to 7-year follow-up. Second-look arthroscopy was performed on 28 patients and showed 20 intact grafts. Two of the 32 patients with Outerbridge grade III chondromalacia and 6 of 11 patients with grade IV changes had failures. This early experience set the stage, showing the importance of intact articular cartilage for success in meniscal transplantation. Noyes and Barber-Westin[30] reported a series of 96 transplants of fresh-frozen, irradiated graft; there was a failure rate of 50% in patients with Outerbridge grade IV chondromalacia. The work of these 2 teams formed the foundation for the recommendation that MAT only be performed in compartments with ≤ grade 2 chondrosis. For completeness, it should be recognized that Stone et al[41] disagree with this limitation and have reported good results for their MAT patients with advanced chondrosis. Rodeo[37] showed the importance of osseous attachment at the meniscal horns, with 88% success with bony fixation, in contrast to 47% in patients without osseous fixation. Since that earlier experience, there have been numerous studies documenting MAT success in ranges near 80%. Most recently, Cole et al[10] published a 2-year follow-up for 44 meniscal transplants. Their results showed 90% of patients returned to normal or near-normal International Knee Documentation Committee scores. In our series, using the Lysholm scale as a reference for grading outcomes, 4 (14%) patients were rated as excellent, 9 (31%) as good, 12 (41%) as fair, and 4 (14%) as poor. This allows some degree of comparison with recent MAT series. While noting the limitation of various outcome tools, there are substantially more fair and poor results in the current combined series than with meniscal transplantation alone.[22,39]

Autologous chondrocyte implantation has been performed in nearly 10 000 patients worldwide, with follow-up of the initial patients to over 16 years. After the initial report of Brittberg et al[5] in 1994, Peterson et al,[34] in 2000, performed a retrospective review of the first 101 patients and showed successful outcomes in 23 of 25 (92%) isolated femoral condyle lesions and 16 of 18 good to excellent results in the treatment of osteochondral defects. At follow-up of the group at 7.5 years, 30 of 31 patients maintained their level of success from the 2-year mark.[7,34] Other international studies have shown comparable results. Separately, Bahuaud et al[3] from France and Spalding from England (unpublished data, 2006) both reported excellent results in 84% and 75%, respectively. These studies involved military personnel, where a majority of them were able to return to full active duty. In a prospective comparison of ACI and mosaicplasty, Bentley et al[4] reported 88% good to excellent results in the ACI group versus 69% in the mosaicplasty group. During second-look arthroscopies at 1 year, there were 82% excellent and good repairs in ACI versus 34% in the mosaicplasty group.

Minas and Chiu[29] reported the results of 235 patients treated with ACI. An 87% success rate was reported over a 6-year period. The majority of patients had coexistent knee injuries as well as early degenerative changes such as osteophyte formation. Gillogly[19] reported on the initial 112 patients treated with ACI; 91% good to excellent results were seen over a 5-year period. The Cartilage Registry Report, an international multicenter observational assessment of patients treated with ACI referenced by Mandelbaum et al[25] in their 1998 review, showed that 78% of patients reported improvement and 81% of ACI-treated isolated femoral condyle defects improved. Despite the positive ACI reports above, the reports by Knutsen et al[21] in 2- and 5-year comparisons of ACI to marrow stimulation failed to show a difference in the 2 techniques; however, the study was not statistically powered to demonstrate a difference. The Knutsen et al[21] study raises issues outside the scope of the current series report. To allow a general comparison with recent ACI series, using a satisfaction scale, the 29 patients included in our study group would be rated as 24% enthusiastic (excellent), 45% satisfied (good), 14% neutral (fair), and 17% unsatisfied (poor).[28]

To our knowledge, this is the first peer-reviewed study that specifically prospectively and purposefully evaluated the results of the combined procedures, acknowledging that other studies have included patients with the combined procedure in their patient pools.[10,19] The goal of our study was to report the initial results of combined ACI and MAT with a minimum 2-year follow-up performed by a single surgeon at a single institution. Overall, patients with the combined procedures showed statistically significant improvement in all scored measurement scales. While the maximum pain score decreased, it remained at a value that is somewhat high. A partial explanation of this pain level (other than the advanced nature of the knee injuries treated) is that maximum pain is a subjective assessment of the pain a patient experiences when he or she tests the knee in a maximal stress situation.

We recognize that a weakness of the study is that concomitant procedures do in fact complicate data interpretation. This is a reality of advanced cartilage restorations; many patients have complex problems. As this is the first peer-reviewed reported series of ACI in conjunction with MAT, we reasoned that a larger inclusive series would promote more discussion than the much more limited subseries of isolated MAT/ACI (noting that there is a suggested statistical trend that there was no difference in isolated versus concomitant surgery patients). To follow a statistically powered series of isolated concomitant MAT and ACI patients over time will likely require a multicenter approach. The study design in that setting could potentially require a staged approach for other knee injuries (eg, performing ACL reconstruction and tibial osteotomy before ACI and MAT) or address this issue with a much larger patient population to allow subgroup statistical evaluation.

In the analysis of the medial versus the lateral group, the study was limited by the number of patients in the lateral group (n = 8). However, nonparametric analysis showed no significant differences between the groups, with the exception of the Lysholm score in which the medial group had a larger improvement. On closer examination of the data, the lateral group showed a trend to a much higher preoperative Lysholm score, which allowed little room for postoperative improvement. Also, a trend toward a higher postoperative maximum pain score was noted in the lateral group. There were no significant differences in the unipolar versus bipolar group; however, the group sizes were small, and 2 of the 4 patients in the bipolar group declined after surgery. The examination of the isolated versus concomitant procedure group again showed no statistical significance in all scoring groups.

Another recognized weakness of the current study is the lack of reporting of radiographic measurement of joint space. However, this was not the focus of the study; rather, the outcome measurements were patient satisfaction and function after the procedure. To allow statistical comment on radiographic measurement of joint space, it would be necessary to position/align the knee using fluoroscopy and then take the Rosenberg view.[26] In the current series, we obtained standard radiographic series, but they were not corrected for magnification with marker films nor positioned using fluoroscopy; therefore, we did not include radiographic analysis in this study.

Recent studies by Verdonk et al[44] and Kelly et al[20] have shown the chondroprotective effect of meniscal transplantation on native articular cartilage through MRI evaluation. Extrapolating from these works, meniscal transplantation may provide a more ideal environment for the healing of ACI. Practically speaking, without an intact meniscus, ACI is contraindicated in the United States per the Food and Drug Administration's Carticel (Genzyme Biosurgery) package insert guidelines. The series does not address the success of surgeons using ACI in compartments without an intact meniscus.[33] On the other side of the equation, the articular cartilage restoration may provide an improved environment for meniscal transplantation. In cases of advanced chondrosis, ACI may provide an option to allow optimization of the articular surface at the time of MAT. Although the early results of the combined procedure in otherwise salvage situations are inferior to either procedure in isolation, the potential of good and excellent results in this challenging population suggests the rationale for pursuing further multicenter studies. Hopefully, with an increase in subject number, statistical powered analysis of patient subsets will allow the development of a scientifically based algorithm that optimizes treatment for each patient who has this difficult constellation of knee injuries.

ACKNOWLEDGMENT

Special thanks to study coordination by Vicki Snodgrass, data coordination by Heidi Thompson, ATC, and statistical analysis by Dr Judy Feinberg.

This research has been approved by the Institutional Review Board of St Francis Hospital, Indianapolis, Indiana.

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