15

Lessons Learned From Our First 100 Meniscus Allograft Transplants in Arthritic Knees

Kevin R. Stone[1], Ann W. Walgenbach[1], and Abhi Freyer[2]

Abstract: The meniscus performs as a knee joint stabilizer and shock absorber as the femoral condyle bears weight on the tibia, translating and rotating on the tibial plateau. A damaged meniscus is often partially removed rather than repaired. Patients without an intact meniscus have few choices: live with the pain, select joint debridement procedures, undergo meniscus allograft transplantation or undergo artificial joint replacement. Despite this, meniscus transplantation has been, until recently, a technique in its infancy. The procedure can be surgically demanding; however, recent studies suggest that meniscus transplantation is a rewarding soft tissue reconstruction that can be useful for arthritic as well as pristine knees to alleviate pain, restore function, and ultimately, delay or avoid joint arthroplasty.

Keywords: Meniscus allograft transplantation, arthritic knees.

15.1. Introduction

Meniscus allograft transplantation was first performed in humans at the turn of the century, but the cases by Milachowski in 1986 stimulated renewed interest in the field [1]. Subsequent to that time, a handful of cases were performed worldwide, but the procedure did not pick up steam until the advent of organized tissue banks in the late 1990s. Even then, meniscus transplantation lagged far behind other musculoskeletal tissue transplantations, with only a few thousand performed as late as 2004. The procedure, until recently, has been in its infancy with many lessons to be learned. This chapter will review our experience with meniscus allograft transplantation and highlight the lessons we have learned over the past few years.

[1] The Stone Clinic, San Francisco, CA
[2] Stone Research Foundation, San Francisco, CA

From: *Orthopedic Biology and Medicine: Musculoskeletal Tissue Regeneration, Biological Materials and Methods.*
Edited by W. S. Pietrzak © Humana Press, Totowa, NJ

15.2. The Meniscus: A Clinical Review

The meniscus performs as a knee joint stabilizer and shock absorber as the femoral condyle bears weight on the tibia, translating and rotating on the tibial plateau. Torn at over 1.2 million times per year in the United States, and frequently excised rather than repaired, the function of this joint cartilage becomes lost. As a result, the knee transmits force abnormally and arthritis and pain result, often years after excision. Treatment of the damaged meniscus has progressed from complete excision, which was advocated in the first three-quarters of the 20th century, to partial excision, and when possible, to repair. It was appreciated by Ahmed and Burke that the percentage and location of meniscus excision was related to the increased force concentration on the tibial plateau, with the most force concentration increase associated with excision of the posterior one-quarter of the medial meniscus [2].

Preservation of the meniscus by suture repair became slightly popular with the advent of arthroscopy and suturing devices popularized by Johnson, Lucas and Dusek, et al. [3]. However, popularity of the procedure was significantly limited due to the difficulty in performing the procedure and the belief that only the most peripheral tears could be repaired. This belief was further enforced by landmark images published by Arnoczky revealing that only the peripheral third of the meniscus had a blood supply [4]. The corollary that the inner margin tears of the avascular portion of the meniscus could not be repaired was not demonstrated; however, it became incorporated into popular belief.

Subsequent studies by Richard Webber demonstrated that the cells of the meniscus could be grown in tissue culture and could migrate [5]. Studies by Stone, et al. demonstrated that the meniscus could be regenerated when provided an appropriate regeneration template made of GAG cross-linked collagen sponges in both dogs and humans. Meniscus reconstruction using these templates is referred to as the “Collagen Meniscus Implant,” or CMI, and has been approved for clinical use in Europe [6]. Efforts to regrow the entire meniscus after complete meniscectomy failed in animal models. This observation is most likely due to the biomechanical properties of the scaffold, not the regeneration potential of the meniscus. Limited regrowth options have left people without an intact meniscus with few choices: live with pain, select joint debridement procedures, undergo complete meniscus allograft transplantation, or undergo artificial joint replacement.

15.3. The Meniscus Allograft

Early efforts at meniscus allograft replacement in knees with pristine surrounding cartilage appeared to provide pain relief and durability [1, 7–12]. The few instances in which a meniscus allograft was placed in an arthritic knee were reported with relatively poor results. This became the often-repeated lore at clinical orthopaedic meetings and in the literature [8, 13–14]. However, the patients who need meniscus replacement are most commonly the 30– to 60-year-olds who have lost their meniscus, often due to sports in college, with resulting compartmental arthritic development. These patients wish to continue living an active lifestyle and want to delay artificial joint arthroplasty until they are older. To serve this need and to answer the questions, “Can meniscus replacement be performed in an arthritic knee and will it last?”, we conducted a prospective outcome study and reported the results in the May 2006 issue of

Arthroscopy: The Journal of Arthroscopic and Related Surgery [15]. We will review this experience here and provide the lessons learned.

15.3.1. Patient Selection

Who is a surgical candidate for a meniscus allograft transplant? Certainly the young person who loses their lateral meniscus to an unfortunate injury or surgery is the most compelling case. Loss of the lateral meniscus always leads to significant degenerative arthritis, which must be prevented by aggressive efforts to repair or replace the meniscus at the time of injury.

Loss of the medial meniscus in a young person is slightly less significant with some whose joints degrade quickly after meniscectomy, and others whose joints degrade over the course of decades. Commonly a very large bucket- handle tear – whether due to lack of skill, confidence, or belief in the healing potential – causes a surgeon to remove rather than repair the meniscus. It is either this meniscectomy, meniscectomy a failed repair, a comminuted and degenerated meniscus, or a cystic meniscus which can often leave the patient unprotected.

Cases in the pristine cartilage setting will do well with a meniscus transplant if the surgery is performed accurately and if the rehabilitation program is protective enough to allow complete healing.

Arthritic knees present the most confusing picture; yet, arthritic patients between the ages of 30 and 60 who lost their meniscus playing high school or college sports and present with predominantly unicompartmental arthritis comprise the largest patient population asking for biologic rather than artificial joint replacement. These patients know the temporary nature of artificial materials. They know the impact sports restrictions of artificial joint replacement. They have heard the horror stories of revisions and infections. They ask the question, "Doc, is there something you can insert into my knee as a shock absorber?" They are content if surgery can be done arthroscopically and if the shock absorber can last even five years. Patients expect that the surgeon could repeat the treatment if the allograft fails or that they will eventually be "old enough" for a knee replacement.

But how arthritic is too arthritic? What are the inclusion and exclusion criteria for biologic joint replacement? Clearly, inflammatory arthritis would be too degradative an environment for cartilage transplantation of any type. Complete eburnation of a compartment with uncorrectable axis deformity prevents insertion of a new meniscus and would lead to rapid failure. However, does eburnation with a neutral or correctable axis deformity present an absolute contraindication? (Fig. 15.1) We do not believe so if the following issues can be dealt with:

Fig. 15.1 Meniscus transplantation in the arthritic knee. (a) Loss of meniscus with exposed eburnated bone of the tibial plateau (b) Insertion of meniscal allograft into the medial arthritic compartment (c) Second-look at the meniscus allograft

Can the eburnation be treated with a cartilage grafting procedure?
We have paste grafted bipolar eburnation and performed meniscus transplants, with or without a concomitant osteotomy, in patients who absolutely refuse artificial joint replacement and understand the risks of the biologic approach [16]. One might speculate that an osteotomy alone for Grade IV arthritis might have been satisfactory, but the documented outcomes for osteotomy are short-term (five-to-seven years for good to excellent results in 80 percent of patients), and it is intuitive that if the osteotomy could be augmented by a soft tissue interpositional arthroplasty (meniscus replacement), then the outcome might be improved.

Is the majority of the pain isolated to the affected compartment?
If the patient complains of pain throughout the knee, a compartment repair is not likely to be sufficient.

Is the joint space narrowing seen on X-ray partially due to impingement of osteophytes, especially at the medial ridge?
If yes, then removal of the osteophytes can reduce the medial pain and result in a joint space appearance that is more reflective of the degree of narrowing.

Is the gait severely abnormal due to mechanical alignment reasons or due to years of favoring and compensation?
This is almost always the case because anyone living with joint pain changes their gait, loses muscle definition, wears out their shoes abnormally, and is often unaware of how much they compensate in life for these deformities. A careful physical therapy assessment and training program, concurrent with surgery and for up to a year postoperatively, can dramatically improve the outcome of the meniscus allograft transplantation procedure.

Is the other knee normal?
If no, correction of one knee without addressing the other knee leads to abnormal favoring and incomplete satisfaction. Generally, significant bilateral varus malalignment and eburnation is better treated with joint arthroplasty in middle-age and older patients. This is not only the case because of the reasons previously discussed, but also because the demands of the long-term rehabilitation program and the increased poor outcome risk of bilateral biologic joint reconstruction seems too high in our minds at this time. However, this thinking may change with improved techniques. The primary concern is the axis correction portion of the reconstruction, which still has a relatively high complication rate and uncertain outcome in middle-aged and older patients.

Is the knee unstable?
If yes, ligament reconstruction should be performed simultaneously with meniscus cartilage transplantation. The common scenarios include anterior cruciate ligament (ACL) deficiency with or without posterolateral corner laxity, and the combination of posterior cruciate ligament (PCL) laxity and medial osteoarthritis. Even in the arthritic knee, ligament reconstruction is beneficial as long as the meniscus is replaced and the arthritic cartilage surface is treated. The fear that the joint will be made “too tight” and produce more pain is unfounded. The biggest risk in all of these procedures, but especially in the combination ligament and meniscus transplantation cases, is the development of arthrofibrosis, which must be combated with an early range-of-motion (ROM) program.

Is the cartilage eburnation too far posterior?
This is a technical problem in that the arthroscopic articular cartilage grafting procedures do not reach the most posterior portions of the femoral condyles. Conversion to an open procedure may be necessary, but we have not needed to do this in our first 200 cartilage paste grafting procedures.

Is the patient contentious and non-compliant?
There is no solution for this, other than going slow and having the surgeon and rehabilitation team get to know the patient. Non-compliance remains an absolute contraindication to biologic knee reconstruction.

15.4. What is the Work-up?

15.4.1. Careful History and Physical

Careful history taking and careful physical examination are crucial initial steps.

In the history taking, the location of pain is one of the early inclusion or exclusion data points. Pain must be primarily unicompartmental. Subjective pain and functioning improvement are important considerations in determining success. A history of litigation, worker's compensation conflicts, anger at former physicians, unwillingness to take time for the rehabilitation program or unrealistic expectations of having a "normal knee" are subjective concerns which, in our hands, often lead to exclusion.

In the physical exam, observation of the patient walking and attempting to run (even in short bursts, i.e., "just to get out of the way of an oncoming truck") are usually sufficient to reveal gait abnormalities that are either correctable or potentially fatal for the biologic repair. Significant posterolateral thrust requires osteotomy. Collapsing arches with loss of motion in the ankle joints require treatment with various modalities such as heel wedges and orthotics. Loss of hip rotation and limping from causes outside of the knee joint must be addressed before the consideration of biologic joint reconstruction can proceed.

An instability examination, focusing on the presence of a pivot shift, is conducted to diagnose medial, posterior, or posterolateral instability. These can be corrected during the same surgery if the diagnosis is made in advance.

The patellofemoral exam is focused not only on the presence of the common occurrence of crepitus, but also on the presence of pain with loading. Significant anterior knee pain post-compartment correction most likely indicates poor patient selection for biologic treatments, but may be addressed with further treatment of the osteochondral defects or arthrofibrosis.

The presence of painful medial or lateral osteophytes, although easily treated, at times requires a small, open incision, as we have found the arthroscopic view deceiving. Removing impinging osteophytes leads to improvement in validated subjective questionnaire pain scores (WOMAC, IKDC, Tegner questionnaires) in our experience.

15.4.2. Careful Imaging Studies

We use current AP, 45-degree PA flexion, lateral, skyline and full-length hip-to-ankle X-ray images on all knees considered for cartilage replacement. We also use a high-field dedicated extremity 1.0 Tesla MRI (ONI Corporation) for all knees with sequences optimized for cartilage imaging.

The most important reasons for MRI in the obviously arthritic unicompartmental knee are to be sure of the status of the cartilage in the patellofemoral and lateral joints, and to assess the degree of osteonecrosis. In our opinion, neither X-ray nor MRI alone is sufficient. Additionally, for outcomes research of the cartilage transplantation procedures, preoperative and postoperative MRIs are the preferred imaging method.

15.4.3. Careful Physical Therapy Assessment

Our in-house therapy team evaluates each patient prior to surgery. The team initiates an exercise program using modalities such as heel wedges, braces, gait training, muscle strength assessment and soft tissue treatment techniques to assist patients to either avoid surgery altogether or to obtain the ideal outcome. The preoperative physical therapy sessions further serve the crucial function of identifying patients who would tend to be non-compliant with proper rehabilitation after surgical intervention.

15.4.4. Careful Nutritional Assessment

The overweight patient presents unique challenges to biologic joint reconstruction procedures and can be counseled to optimize their weight and training program. All patients are encouraged to focus on a core strengthening program with a diet supporting weight loss and strengthening. All patients are encouraged to use glucosamine as a natural anti-inflammatory and a stimulant to cartilage repair. A beverage-based supplement (Joint Juice, Inc.) may result in a higher compliance rate and enhanced bioavailability over pill-based forms.

15.5. Surgical Technique

Our surgical technique was previously published [18], and our long-term results [15] will be summarized here with a focus on surgical tips and tricks we have learned from our first 100 meniscus allograft transplants in arthritic knees.

15.5.1. Setup

Our "all-arthroscopic" meniscus transplantation technique is accomplished by having tight control of the femur because the leg often needs to be stressed in the oblique direction. This can only be accomplished with a circumferential leg holder. We prefer the Smith and Nephew Surgical Assistant Leg Holder (Smith and Nephew Inc., Memphis, Tennessee). Leg posts, human holders and open "U" designs do not permit the same angulation and easy visualization of the knee, especially for the posterior edges of the menisci. The end of the operating room table is either fully bent or removed. Instruments are placed on a Mayo stand above the patient's abdomen. No tourniquet is used; water pump infiltration provides homeostasis without the time pressure of the tourniquet.

15.5.2. Surgical Tips

15.5.2.1 Initial Preparation: Visualization

A complete arthroscopy and treatment of other issues, such as ligament instability, precedes meniscus transplantation. However, if an ACL reconstruction is to be performed, drill the holes but do not place the allograft until the end of surgery, to allow for the extra laxity necessary for visualization.

The next step to improve visualization is to trim the edges of the remaining meniscus cartilage, thereby freshening the blood supply while maintaining the rim of the meniscus to receive the allograft. Preserving the rim is the key to preventing subluxation into the medial or lateral gutter and "shrinkage" of the allograft. Avoid using any electrocautery or bipolar units on the meniscus, as blood supply determines the rate of healing. The trick to trimming the anterior one-quarter of the meniscus is to use a backbiter, both right- and left-sided. The meniscus is then needled using a smooth drill pin passed through an AO-drill guide, modified by rounding the tip of the guide to diminish the chance of scuffing the surrounding articular cartilage. The needling brings in a new blood supply and creates channels for cellular ingrowth [17]. On the medial aspect, the needle is passed repeatedly through the medial collateral ligament, creating a "Swiss cheese" effect. When valgus force is applied, opening of the joint is permitted even in the tightest of knees.

15.5.2.2. Medial Meniscus

15.5.2.2.1. Tunnel Placement: The three-tunnel technique for the medial meniscus requires that the three holes be placed optimally for meniscus insertion and fixation [18]. The posterior hole is made with a custom-modified guide that has a concave superior curvature to allow passage under the femoral condyle. The tip has a spoon to protect against unfortunate drill passage into the posterior neurovascular structures. The tip of the guide has a point, which must be placed at the bottom of the posterior medial eminence next to the PCL insertion. A drill pin is passed from the anterior tibial cortex into the spoon while watching and feeling the pin to avoid past-pointing. A 7 mm cannulated drill is then driven over the pin under direct visualization, with a curved curette positioned to catch the drill pin. If the guide pin is placed higher up or more anterior on the tibial plateau, the resulting anterior edge of the 7 mm hole will permit anterior subluxation of the meniscus, resulting in either tearing of the posterior horn or loss of flexion. This is the most common mistake in medial meniscus transplantation.

The 7 mm drill is left in place and a suture passer with a #1 nylon loop is passed up the bore and brought out through the medial portal. The drill is then removed. Prior to pulling out the nylon loop, the medial portal must be thoroughly cleared of soft tissue or else the implant will catch upon insertion. We use a large shaver, followed by an oval obturator and then followed by a large clamp spread wide in the 2 cm portal. Failure to do this leads to much frustration upon allograft insertion.

The second hole is placed one-quarter of the way around the tibia from the posterior insertion; approximately 1 cm away, but still facing the posterior aspect of the knee, not around the corner facing the medial aspect. A 4.5 mm cannulated drill is used here, since the meniscus will not be dunked into the hole. A blue PDS® suture loop is passed and brought out through the medial portal. Different size clamps are utilized to keep the sutures sorted.

The third, anterior, hole is placed by identifying the natural insertion site of the recipient, which is often over the anterior edge of the tibial plateau. A straight AO guide is placed followed by a drill pin buried only 1 cm into the bone. This is over-drilled with the 7 mm drill through the medial portal to a depth of 1 cm, thereby creating a socket to insert the anterior horn of the meniscus. A triangle drill guide is placed into the socket and a pin placed from the anterior medial tibial cortex to the tip of the guide and then over-drilled with the 4.5 mm cannulated drill. Again, a nylon suture loop is passed and exited through the medial portal.

15.5.2.2.2. Graft Preparation: Next, the meniscus allograft is prepared on the back table by separating it from the tibial plateau with a knife, retaining the periosteum at the anterior and posterior ligamentous horn insertions. A different colored, strong permanent suture is then weaved into the horns and the posterior quarter, matching the distance from the horn to the posterior hole. The bottom of the meniscus is marked with a skin marker to create "Walgenbach" lines, which assist in the differentiation between the top and bottom of the allograft should twisting occur. The horns and corner stitches are loaded into the loop stitches and pulled into the knee. A common mistake is twisting the posterior and corner stitches onto each other, which prevents seating of the allograft. This must be identified, and the meniscus must be removed and untwisted. Once seated, clamps are placed on the suture against the anterior tibia as temporary fixation.

15.5.2.2.3. Graft Fixation: We prefer an inside-out suture technique, utilizing curved, cannulated guides. We avoid making large open posterior, medial or lateral incisions and instead prefer making two or three small stab wounds, which can be stretched to retrieve the passed suture needles. We use 10-inch needles with PDS® suture, taking care to pass them both above and below the meniscus in vertical stitch orientation. It is important to note that the bottom of the allograft must be sewn to the bottom of the meniscus remnant rim; the top of the allograft to the top of the meniscus remnant. Avoid sewing directly to the synovium or the meniscus will sublux into the gutter. We sew from back to front, changing the angle for the guides as needed. When the meniscus looks balanced, the anterior, corner and posterior permanent sutures are tied while visualizing the tension on the meniscus. These sutures are tied prior to tying the knots on the middle of the meniscus to avoid pulling the horns away from the tunnel insertions. To tie the most anterior aspect of the meniscus, we use Caspari suture guides to pass two stitches and tie those to the anterior meniscus rim through the incision.

Finally, the knee is taken through a full range of motion and meniscus stability is checked with a probe.

15.5.2.3. Lateral Meniscus

The lateral meniscus insertion varies only in that a trough is made with #5.5 round burr between the anterior and posterior horns, and is checked with a curved curette. 4.5 mm drill holes are placed at either edge of the trough and sutures are passed. The meniscus allograft is trimmed with an oscillating saw and osteotomes to a 5 mm-wide block. The anterior corner and posterior sutures are placed as described above, and the meniscus is inserted with manual pressure through the slightly widened medial portal and pulled to the lateral side.

15.6. Postoperative Rehabilitation

The primary goal of the meniscus allograft rehabilitation protocol is to protect and preserve the allograft, with a secondary goal of restoring range of motion. General considerations include partial weight bearing status for four weeks postoperatively; 10 percent to 20 percent toe touch for one to two weeks; a hinged rehabilitation brace locked in full extension for four weeks postoperatively, unless otherwise indicated; regular assessment of gait to avoid compensatory patterns; regular manual mobilizations to surgical wounds and associated soft tissue to decrease the incidence of fibrosis; no resisted leg extension machines; no high-impact, cutting, or twisting activities for at least four months postoperatively; and stretching five times daily by bending the knee back as far as tolerated for 10 seconds.

The rehabilitation protocol can be described in two phases: a maximal protective phase and a moderate protective phase. The maximal protective phase is from weeks 1 to 4, and includes activities as follows:

Week 1:

- M.D. visit Day One postop to change dressing and review home program
- Icing and elevation regularly. Aim for five times per day, 15 to 20 minutes each time
- Cryotherapy machine as directed
- Soft tissue treatments to musculature for edema and pain control
- Daily manual patella glides (up/down/side-to-side) by therapist and patient
- Exercises:
  - Straight leg raise exercises (lying, seated, and standing): quadriceps/adduction/abduction/gluteal sets
  - Twice daily passive and active range-of-motion exercises
  - Theraband calf presses
  - Well-leg stationary cycling
  - Upper body training
  - Core/trunk training

Weeks 2 to 4:

- M.D. visit at eight-to-ten days postop for suture removal and check-up
- GENTLE and BRIEF pool/deep-water workouts after the first eight-to-ten days and with the use of a brace. No more than 30 minutes per workout and no more than three workouts per week
- Continue with pain control, gentle range-of-motion and soft tissue treatments M.D. visit at four weeks post-op

The moderate protective phase is from four-to-twelve weeks and includes stretching, manual treatments to restore range-of-motion, the introduction of functional exercises (i.e., partial squats, calf raises and proprioception exercises), road cycling as tolerated, slow walking on a low-impact treadmill and lateral training. Exercises increasingly focus on single-leg exercises, strength training and sport-specific training for a gradual return to activities.

Weeks 5 to 6:

- Patients progress to full weight bearing and discontinue use of rehab brace
- Increase stretching and manual treatments to improve knee range-of-motion Extension should be full and flexion should be near 100 degrees
- Incorporate functional exercises (i.e., partial squats, calf raises, mini step-ups, light leg pressing and proprioception)
- Stationary bike and progressing to road cycling as tolerated
- Slow walking on treadmill for gait training (preferably a low-impact treadmill)
- Gait training to normalize movement patterns

Weeks 7 to 8:

- Increase the intensity of functional exercises (i.e., cautiously increase depth of closed-chain exercises, shuttle/leg press). Do not overload closed- or open-chain exercises
- Continue to emphasize normal gait patterns
- Range-of-motion: Full extension and flexion to 120 degrees

Weeks 9 to 12:

- Add lateral training exercises (side step-ups, Theraband resisted side-stepping, and lateral stepping)
- Introduce more progressive single-leg exercise
- Patients should be pursuing a home program with emphasis on sport/activity-specific training
- Range of motion should be near normal

Weeks 13 to 16:

- Low-impact activities until 16 weeks
- Increase intensity of strength and functional training for gradual return to activities

15.7. Summary of Published Results

The published data of our prospective, longitudinal survival study of meniscus allograft replacement presents survival data at least two years from surgery for 45 patients with significant arthrosis (47 allografts) to determine if the meniscus can survive in an arthritic joint (Table 15.1). Data was collected for 31 men and 14 women, with mean age of 48 years (range: 14 to 69 years), with preoperative evidence of significant arthrosis and an Outerbridge classification greater than II. Failure was established by previous studies as allograft removal. No patient was lost to follow-up. The success rate was 42 of 47 allografts (89.4 percent) with a mean failure time of 4.4 years as assessed by Kaplan-Meier survival analysis. Statistical power was greater than 0.9, with $\alpha = 0.05$ and $N = 47$. There was significant mean improvement in preoperative versus postoperative self-reported measures of pain, activity, and functioning, with $p = .001$, $p = .004$ and $p = .001$, respectively, as assessed by a Wilcoxon rank-sum test with significance set as $p < .05$.

In this series, 29 allografts were cryopreserved (62 percent) and 18 were fresh-frozen allograft material (38 percent). Four of the five failures (80 percent) were of cryopreserved allograft material. A statistically significant failure rate based on allograft material was not observed, possibly because of the low number of failures.

Meniscus allografts can survive in joints with arthrosis, which challenges the contraindications of age and arthrosis severity. Figure 15.2 is representative of the level of arthrosis and long-term outcome observed in patients of this study. These results compare favorably with those in previous reports of meniscus allograft survival in patients without arthrosis [1, 7–12, 15].

15.8. Future Trends and Needs

Our experience confirms that a meniscus allograft can survive for two-to-seven years in the presence of chondromalacia in the same compartment. Whether it functions as a normal meniscus, or simply as an interpositional

Table 15.1 Summary of meniscus transplantation outcomes [15]

STUDY	Patients (Allografts)	Mean F/U Years (Range)	Mean Age Years (Range)	Allograft Material	Arthrosis Grade (n)	Failures (%)	Failure Criteria
Less Than Severe Arthrosis (OB Gr 0 - Gr III)							
Milachowski [1] (1989)	22 (22)	1.1 (0.33–2.5)	29.6 (21–45)	Deep frozen (6) Lyophilized w/ γ-irradiation (16)	Gr I (2) Gr II (10) Gr III (1) Normal (8) Unaccounted (1)	9.1	Undefined: Self assessment
Rath [10] (2001)	18 (22)	4.5 (2.0–8.1)	30 (19–41)	Deep frozen & Cryopreserved w/ bone plugs	Severe arthrosis excluded.	9.1	Allograft removal
Noyes [8] (2003)	34 (35)	3.1 (1.9–5.8)	28 (14–46)	Cryopreserved	Gr II Gr III	8.6	Allograft removal
					Total Mean Failure	**8.9% (7/79)**	
Includes Arthrosis (OB Gr IV)							
van Arkel [12] (1995)	23 (25)	3 (2–5)	41 (30–55)	Cryopreserved	Gr II (1) Gr III (23) Gr IV (1)	12	Allograft removal
Potter [9] (1996)	24 (29)	1.1 (0.25–3.4)	33.2 (24–43)	Fresh-frozen NOT γ-irradiated	Gr I–II (2) Gr III–IV (22)	3.4	Allograft removal
Cameron [7] (1997)	63 (67)	2.6 (1.0–5.5)	41 (11 pts > 50)	Fresh-frozen γ-irradiated	Gr II Gr III Gr IV	4.5	Allograft removal
Stollsteimer [11] (2000)	22 (23)	3.3 (1.1–5.8)	31 (20–42)	Cryopreserved w/ bone plugs	Gr I Gr II Gr III Gr IV	4.3	Post-Op infection & OB score
Stone (2006) [15]	45 (47)	4.5 (2–7)	48 (14–69)	Cryopreserved & fresh-frozen	Gr III (9) Gr IV (38)	10.6	Allograft removal
					Total Mean Failure	**6.8% (13/191)**	

[15] Reprinted from Arthroscopy: The Journal of Arthroscopic and Related Surgery, Vol 22. Stone KR, Walgenbach AW, Turek TJ, Freyer A, Hill M.D. Meniscus Allograft Survival in Patients with Moderate to Severe Unicompartmental Arthritis: A 2- to 7-Year Follow-up. 469–478 Copyright (2006) with permission from Arthroscopy Association of North America.

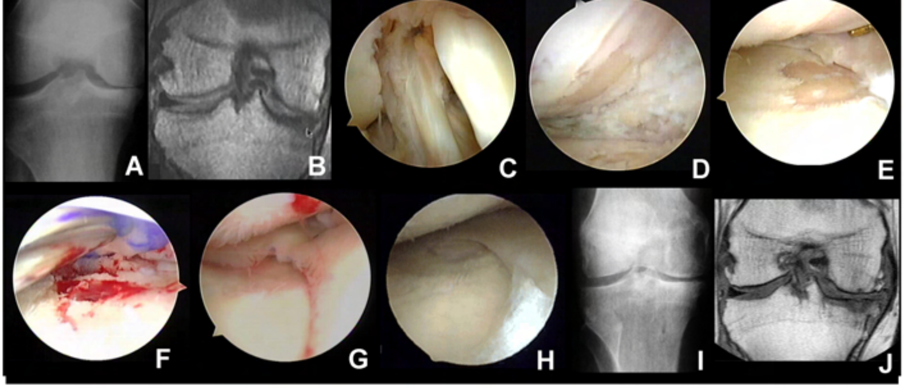

Fig. 15.2 Preoperative, operative, and postoperative images of meniscus allograft transplantation. (a) Preoperative PA flexion radiograph of a 39-year-old male one-year post-meniscectomy with noticeable joint space narrowing (b) Preoperative coronal MRI documenting lateral meniscus bucket handle tear and bipolar cartilage lesions (c) Arthroscopic view of the right knee bucket handle tear displaced into intercondylar notch (d, e) Eburnation of the femoral condyle and tibial plateau (f) Microfracture of the tibial plateau (g) Placement of the meniscus allograft (h) Arthroscopic view of the allograft 17 months postoperatively (i) AP radiograph five years postoperatively showing improved joint space (j) Five-year postoperative coronal MRI revealing the transplanted meniscus present and maturing degenerative changes

soft tissue arthroplasty, was not addressed by this study. The improvements noted in pain and functioning may be attributed to the transplant, the concomitant procedures, the rehabilitation program, or the attentive care of the medical team. The goal of the study was to determine if the graft could survive in an arthritic knee. A controlled study comparing arthroscopy with and without meniscus allograft transplantation will help clarify the implant's contribution. Compared with other outcome studies, patients in this study had successful meniscus allografts in spite of being older and having well-documented severe degenerative disease, both of which were previously believed to be contraindications for meniscal allograft transplantation. These results show that meniscal allograft transplantation can be used in higher risk patients with reasonable expectations for allograft survival. This study reveals that the previous contraindications of age and severity of arthrosis are overstated, and that these results are comparable to those of other studies whose patients were younger and without arthrosis.

15.9. Conclusions

In summary, meniscus transplantation requires attention to detail, but is a soft tissue reconstruction that can be useful for pristine as well as arthritic knees.

References

1. Milachowski KA, Weismeier CJ, Wirth CJ. Homologous meniscus transplantation: Experimental and clinical results. *Int Orthop.* 1989;13:1–11.
2. Ahmed AM, Burke DL. In-vitro measurement of static pressure distribution in synovial joints. Part I. Tibial surface of the knee. *J Biomech Eng.* 1983;105:216–25.

3. Johnson MJ, Lucas GL, Dusek JK, Henning CE. Isolated arthroscopic meniscal repair: a long-term outcome study (more than 10 years). *Am J Sports Med*. 1999 Jan-Feb;27(1):44–9.
4. Arnoczky SP, Warren RF. Microvasculature of the human meniscus. *Am J Sports Med*. 1982 Mar-Apr;10(2):90–5.
5. Webber RJ. In vitro culture of meniscal tissue. *Clin Orthop Relat Res*. 1990 Mar;(252):114–20.
6. Stone KR, Steadman JR, Rodkey WG, Li ST. Regeneration of meniscal cartilage with use of a collagen scaffold. Analysis of preliminary data. *J Bone Joint Surg Am*. 1997 Dec;79(12):1770–7.
7. Cameron JC, Saha S. Meniscal allograft transplantation for unicompartmental arthritis of the knee. *Clin Orthop Relat Res.* 1997;337:164–171.
8. Noyes FR, Barber-Westin SD. Role of meniscus allografts alone and combined with ACL reconstruction or osteochondral autograft transfer procedures. Presented at the Annual Meeting of the AOSSM, New Orleans, LA, 2003.
9. Potter HG, Rodeo SA, Wickiewicz TL, Warren RF. MR imaging of meniscal allografts: correlation with clinical and arthroscopic outcomes. *Radiology*. 1996 Feb;198(2):509–514.
10. Rath E, Richmond JC, Yassir W, Jeffreys DA, Gundogan F. Meniscal allograft transplantation two- to eight-year results. *Am J Sports Med.* 2001;29:410–414.
11. Stollsteimer GT, Shelton WR, Dukes A, Bomboy AL. Meniscal allograft transplantation: A 1-to 5-year follow-up of 22 patients. *Arthroscopy.* 2000;16:343–347.
12. van Arkel ERA, de Boer HH. Human meniscal transplantation: Preliminary results at 2 to 5-year follow-up. *J Bone Joint Surg Br.* 1995;77:589–595.
13. Fairbank TJ. Knee joint changes after meniscectomy. *J BoneJoint Surg Br.* 1976;30:664–670.
14. Zukor DJ, Cameron JC, Brooks PJ, et al. The fate of human meniscal allografts. In: Ewing W, ed. *Articular cartilage and knee joint function: Basic science and arthroscopy*. New York: Raven, 1990;147–152.
15. Stone KR, Walgenbach AW, Turek TJ, Freyer A, Hill MD. Meniscus Allograft Survival in Patients with Moderate to Severe Unicompartmental Arthritis: A 2- to 7-Year Follow-up. *Arthroscopy*. 2006; 469–478.
16. Stone KR. Articular cartilage repair—The paste graft technique. Insall JN, Scott WN, eds. *Surgery of the Knee*. Ed 3. Philadelphia: Churchill Livingstone, 2001;375–380.
17. Zhang Z, Arnold JA: Trephination and suturing of avascular meniscal tears: a clinical study of the trephination procedure. *Arthroscopy*. 1996;12(6):726–731.
18. Stone KR, Walgenbach AW. Meniscal allografting: The three tunnel technique. *Arthroscopy.* 2003;19:426–430.