Results and Indications

5

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5.1 Indications and Contraindications

5.1.1 Indications

According to current recommendations, meniscal allograft transplantation is indicated in three specific clinical settings:

1. Young patients with a history of meniscectomy who have pain localized to the meniscus-deficient compartment, a stable knee joint, no malalignment, and articular cartilage with only minor evidence of osteochondral degenerative changes [no more than grade 3 according to the International Cartilage Repair Society (ICRS) classification system (Table 5.1)], are considered ideal candidates for this procedure. Some studies [1–6] have shown that meniscal allografts can survive in an osteoarthritic joint (Outerbridge grade 3–4), with significant improvement in pain and function. Because of the more rapid deterioration in the lateral compartment [7], a relatively common indication for meniscal transplantation would be a symptomatic, meniscus-deficient, lateral compartment.
2. Anterior cruciate ligament (ACL)-deficient patients who have had previous medial meniscectomy with concomitant ACL reconstruction and who might benefit from the increased stability afforded by a functional medial meniscus. It is the authors' conviction, that an ACL graft is significantly protected by the meniscus allograft as much as the meniscus is protected by an ACL graft.

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Table 5.1 International cartilage repair society cartilage lesion evaluation system

Grade 0	Normal
Grade 1	Superficial lesions, softening, fissures or cracks
Grade 2	Lesions, erosion or ulceration of less than 50 %
Grade 3	Partial-thickness defect of more than 50 % but less than 100 %
Grade 4	Ulceration and bone exposure

3. In an effort to avert early joint degeneration, some also consider young, athletic patients who have had total meniscectomy, as candidates for meniscal transplantation prior to symptom onset [8]. *However, the results obtained so far still preclude a return to high-impact sports.*

5.1.2 Contraindications

Advanced chondral degeneration is considered a contraindication to meniscal allograft transplantation, although some studies suggest that cartilage degeneration is not a significant risk factor for failure [9]. In general, greater than grade 3 articular cartilage lesions according to the ICRS classification system should be of limited surface area and localized. Localized chondral defects may be treated concomitantly, as meniscus transplantation and cartilage repair or restoration may benefit each other in terms of healing and outcome [10]. Chondrocyte transplantation or osteochondral grafting procedures should be performed after completion of the meniscal transplantation in order to prevent accidental damage to the patch or graft during meniscal allograft insertion [11]. Radiographic evidence of significant osteophyte formation or femoral condyle flattening is associated with inferior postoperative results because these structural modifications alter the morphology of the femoral condyle [12]. Generally, patients over age 50 have excessive cartilage lesions and are suboptimal candidates.

Axial malalignment tends to exert abnormal pressure on the allograft leading to loosening, degeneration, and failure of the graft [12]. A corrective osteotomy should be considered in patients with more than two degrees of deviation toward the involved compartment, as compared with the mechanical axis of the contralateral limb. Varus or valgus deformity may be managed with either staged or concomitant high tibial or distal femoral osteotomy [11]. However, as in any situation in which procedures are combined, it is unclear which aspect of the procedure is implicated in symptom resolution, such as relief of pain [12].

Other contraindications to meniscal transplantation are obesity, skeletal immaturity, instability of the knee joint (which may be addressed in conjunction with transplantation), synovial disease, inflammatory arthritis and previous joint infection, and obvious squaring of the femoral condyle.

5.2 Results

It is difficult to perform a meta-analysis of all the published results, because of the small populations studied and the differences (Table 5.2) in indications, contra-indications, preservation techniques, preoperative Outerbridge grade, fixation techniques, surgical techniques, concomitant procedures, evaluation tools and rehabilitation protocols.

In this chapter, we will try to present outcome data based on a review of the literature. A total of 39 studies have been included, representing 1,226 meniscus allografts (626 medial vs. 446 lateral, 154 not specified) in 1,145 patients. The mean age at the time of surgery was 34.4 years. The mean follow-up was 5.5 years. Overall, 340 isolated allograft transplantations were analysed, 427 were associated with ACL reconstruction, 107 with a corrective osteotomy and 215 with other procedures. It was not specified whether the remaining 137 allografts were associated with other procedures. Concerning the surgical fixation technique, 631 allografts were fixed using bone blocks and 488 using a soft-tissue fixation technique. For 107 allografts the fixation method was not specified. In the next paragraphs, the outcome is reported independently of the aforementioned parameters.

Methods to evaluate the success or failure of meniscal transplantation range from subjective pain scale measurements and patient perceptions of function to objective measurements such as physical and radiological examinations, magnetic resonance imaging (MRI), and second-look arthroscopy.

5.2.1 Subjective Assessment

All studies showed significant subjective improvement in pain scales and functional activity questionnaires. The data from most studies are summarized in Table 5.3. In general, isolated procedures and combined procedures tended to have similar outcomes. No differences were observed based on tissue preservation technique or fixation method. About 75–90 % of patients experienced fair to excellent results.

5.2.2 Objective Clinical Scoring

5.2.2.1 Physical Examination

Almost all studies reported equal or improved physical examination findings at follow-up with regard to range of motion, pain, effusion, stability, function tests or IKDC score. The data from most studies are summarized in Table 5.4.

Table 5.2 The difficulty realizing a meta analysis of all the published results, because of the small populations studied and the differences in indications, contraindications, preservation techniques, preoperative outerbridge grade, fixation techniques, surgical techniques, concomitant procedures, evaluation tools and rehabilitation protocols

Nr	Authors	Year P	Year S	# grafts	M	L	# patients	Age	Time M-TX	Preservation	Rad?	Fix	FUT	Preop cart	# isolated	Concomm. procedures
1.	Cameron and Saha.	1997	1988–1994	67	37	30	63	41	16.7	DF	Yes	S	2.5	2–4	21	5ACL, 34OT, 7ACL+OT
2.	Carter et al.	1999	NA	46	39	7	46	NA	NA	Cryo.	NA	B	2.8	NA	NA	30ACL, 4OT, 1MCL
3.	Garrett et al.	1993	NA	43	34	8	43	NA	NA	16DF, 27Cryo.	NA	B	4.5	NA	7	24ACL, 13OT, 11OAL
4.	Goble et al.	1999	NA	69	48	21	60	NA	NA	Cryo.	NA	B	2	NA	NA	28ACL
5.	Groff et al.	2001	1993–1998	16	0	16	16	27	8	DF	No	B	3.8	1–2	16	None
6.	Wirth et al.	2002	1984–1986	22	22	0	22	29.6	NA	6DF, 16Lyo.	6No, 16Yes	S	3/14	1, 6	0	22ACL, 19MCL
7.	Noyes et al.	1995	NA	96	79	17	83	NA	NA	DF	Yes	B	<2	NA	19	77ACL
8.		2004	1995–2000	40	20	20	38	30	NA	Cryo.	No	B	3.3	3, 6	NA	7ACL, 1PCL, 1ACL+PCL, 1MCL, 16 OAU
9.	Rath et al.	2001	1991–1997	22	15	7	18	30	7.7	Cryo. + DF	No	1S, 21B	4.5	NA	3	11ACL, 1TTT
10.	Stollsteimer et al.	2000	1991–1995	23	11	12	22	31	3.8	Cryo.	No	B	3.3	COB: 5, 6	23	None
11.	Van Arkel et al.	2000	1994–1995	19	6	13	16	40	16	Cryo.	No	NA	2.7	NA	NA	NA
12.		2002	1989–1999	63	23	40	57	39	16	Cryo.	No	S	5	NA	61	2ACL
13.	Verdonk et al.	2004	NA	27	0	27	27	33,9	NA	V	No	S	1	NA	NA	NA
14.		2005	1989–2001	100	39	61	96	35	NA	V	No	S	7.2	2.5	69	3ACL, 17OT, 3Mi, 4OPT
15.		2006	1989–1993	39	NA	NA	38	35.4	NA	V	No	S	12.1	2.7	NA	3ACL, 12OT

(continued)

Table 5.2 (continued)

Nr	Authors	Year P	Year S	# grafts	M	L	# patients	Age	Time M-TX	Preservation	Rad?	Fix	FUT	Preop cart	# isolated	Concomm. procedures
16.	Shelton and Dukes	1994	NA	14	5	9	14	NA	NA	Cryo.	NA	B	NA	NA	NA	NA
17.	Veltri et al.	1994	NA	16	8	8	14	35,3	11,3	DF + Cryo.	No	B	0.7	NA	4	10ACL, 1PCL, 1ACL+PCL
18.	Cole et al.	2006	1997–2003	40	25	15	36	31	NA	32DF + 8Cryo.	No	B	2.8	<4	21	ACL, 1OT, 3OAL, 3OAU, 1ACI, 2Mi, 2 ODfix
19.	Rodeo et al.	2000	1989–1995	33	17	16	28	34	NA	DF	No	20B, 13S	1.3	NA	8	19ACL, 1OT
20.	Del Pizzo et al.	1996	1991–1994	19	NA	NA	19	NA	NA	19Cryo.	NA	NA	3.2	NA	6	11ACL, 2OT
21.	Yoldas et al.	2003	1993–1996	34	NA	NA	31	28	8	DF	No	B	2.9	NA	11	20ACL
22.	Ryu et al.	2002	1993–1999	26	10	16	25	34.5	NA	NA	NA	B	2.75	2.8	12	14ACL
23.	Hommen et al.	2007	1991–1995	20	12	8	20	32	NA	20Cryo.	No	13S, 7B	11.7	2.2	5	10ACL, 2OT, 3CHFC, 2CP, 3LR
24.	Cryolife	1997	1989–1994	1023	747	276	1015	NA	NA	Cryo.	NA	930B, 92S	7	NA	NA	NA
25.	Felix and Paulos	2002	1993–1999	36	20	16	33	28.5	6	Cryo.	No	B	5.2	NA	9	18ACL, 2OT, 4ACL+OT
26.	Vacquero et al.	2003	2001–2002	32	NA	NA	30	37	NA	DF	No	B	>1	2, 3	NA	6ACL, 3Mi, 7RFA, 1TTT
27.	Sekiya et al.	2003	1994–1998	31	24	7	28	35	8.6	Cryo.	No	B	2.8	1–4	0	28ACL, 2ACL+OT
28.		2006	1993–1998	25	0	25	25	30	5.7	Cryo.	No	8S, 17B	3.3	1–4	25	None

(continued)

Table 5.2 (continued)

Nr	Authors	Year P	Year S	# grafts	M	L	# patients	Age	Time M-TX	Preservation	Rad?	Fix	FUT	Preop cart	# isolated	Concomm. procedures
29.	Potter et al.	1996	1989–1996	29	14	15	24	33.2	NA	DF	NA	B	NA	2–4	11	16ACL, 1OT, 1MCL
30.	Stone et al.	2006	1997–1999	47	37	10	45	48	NA	18DF, 29Cryo.	No	S	5.8	3.8	7	6ACL, 17OT, 19Mi, 47CHFC, 24ACPG
31.	Fukushima et al.	2004	1996–1997	43	30	13	40	37.3	11.4	Cryo.	No	S	1	NA	NA	8ACL, 1OT
32.	Rankin et al.	2006	NA	8	5	3	7	31	NA	Cryo.	No	B	2	2.9	2	4ACL, 4OAU
33.	Bhosale et al.	2007	NA	8	2	6	8	43	14	Cryo.	No	S	3.2	3.8	0	8ACI
34.	Graf et al.	2004	1990–1992	8	8	0	8	32.6	10.5	Cryo.	1No, 7Yes	7S, 1B	9.7	NA	0	8ACL, 1OT, 8ACL+OT
35.	Rueff et al.	2006	NA	8	8	0	8	52	NA	Cryo.	No	B	5.5	NA	0	8ACL
36.	Von Lewinski et al.	2007	1984–1986	6	6	0	6	25	NA	DF	No	S	20	2.6	0	6ACL
37.	Milachowski et al.	1989	NA	22	22	0	22	NA	NA	NA	NA	NA	1, 2	NA	0	22 ACL
38.	Barrett et al. (unpublished data)	1996	NA	15	NA	NA	15	NA	NA	Cryo.	NA	NA	5	NA	NA	NA
39.	Dienst and Kohn											S	3–7			
40.	Kim and Bin	2006	1996–2003	14	NA	NA	14	NA	NA				4.8			

Abbreviations Year P year of publication, *Year S* years of surgery, *#* number of, *M* number of medial grafts, *L* number of lateral grafts, *Time M-TX* average time in years from meniscectomy to transplantation, *Age* average age of patients at time of transplantation in years
Rad? radiation of graft?, *Preop. Cart.* preoperative cartilage outerbridge grade, *Fix* fixation technique used to fix the allograft, *B* bony fixation, *S* only sutures, *FUT* average time of follow-up in years, *#* isolated number of transplantation without Concomitant procedures
OT osteotomy, *OAL* osteochondral allograft, *OAU* osteochondral autograft, *ACL* anterior cruciate ligament reconstruction, *PCL* posterior cruciate ligament reconstruction, *MCL* medial collateral ligament reconstruction, *NA* not available, *DF* deep-frozen, *Cryo.* cryopreserved, *Lyo.* lyophilised, *V* viable, *TTT* tuberositas tibiae transfer, *COB* cumulative outerbridge score: calculated by adding the scores for all areas of each knee, *Mi* microfracture, *OPT* osteochondral plug transfer, *ACI* autologous chondrocyte implantation
ODfix osteochondritis dissecans fixation, *CHFC* chondroplasty femoral condyle, *CP* capsular plication, *LR* lateral retinaculum release, *RFA* radiofrequent ablation, *ACPG* articular cartilage past grafting

Table 5.3 Summary of subjective assessment

1.	Cameron et al.	1997	87 % good to excellent rate. (85 % after 3 years) Fulkerson (=modified Lysholm) functional knee score, Tegner score, Reduction in need of anti-inflammatory medication: SI
2.	Carter et al.	1999	IKDC: SI
3.	Goble et al.	1999	Quality of life (regarding pain at rest, during recreational activity and functional stability): SI
4.	Groff et al.	2001	Lysholm score: 91 % fair to excellent ratio
			IKDC: 91 % nearly normal to normal
			All (100 %) were improved, 100 % satisfaction with the condition of their knee as a result of the surgery
			SF-36: 6 of 8 categories higher scoring than age and sex matched population
			KOS at FUT: ADLS: 79.3 SAS: 74.5
			41 % had pain with light sports activities
5.	Wirth et al.	2002	Lysholm, Tegner (at 3y/14y FUT): SI (deep-frozen better than lyophilized, but both deterioration after 14y) (influenced by preoperative cartilage condition and instability)
6.	Noyes et al.	2004	Perception of knee condition: 73 % good to normal. 89 % Improvement of knee function
			76 % Participation in light low-impact sports
			Cincinnati score: SI
7.	Heckmann et al.	2006	94 % improvement of knee condition
			77 % participation in light low-impact sports
8.	Rath et al.	2001	SF-36 for bodily pain, role physical, physical functioning and social functioning: SI
			Mean IKDC functional score: 54
9.	Stollsteimer et al.	2000	Improvement of preoperative pain in 82 %. Tegner score, IKDC score, Lysholm: SI
			Articular cartilage changes preoperatively and preoperatively higher IKDC score had significant effect on overall patient outcome score
10.	Van Arkel et al.	2000	KASS: 84 % successful result
			Modified Lysholm: 84 % fair to excellent
			Tegner: SI
11.	Van Arkel et al.	2002	77 % success
			Lysholm: SI
			91 % improvement of pain

(continued)

Table 5.3 (continued)

12.	Verdonk et al.	2005	Relieve in pain and improved function at 10 years in 70 %
13.	Verdonk et al.	2006	90 % were satisfied with the operation and would do it again
14.	Cole et al.	2006	75 % completely/mostly satisfied with procedure: 68 % medial, 93 % lateral, 81 % isolated, 74 % "combined with other procedure" subgroup
			Lysholm, Tegner, Noyes, IKDC, KOOS pain, symptom, ADL and sports, SF-12 PCS score, VAS pain and overall knee condition: SI
			86 % would have surgery again: 84 % medial subgroup, 93 % lateral subgroup, 86 % isolated and 84 % in combined subgroup
15.	Rodeo et al.	1998	88 % of bone plugs + 47 % soft tissue fixated transplantations were rated as GOOD OR MODERATE.
			Lysholm, IKDC, VAS: pain + function: SI
16.	Rodeo et al.	2000	58 % clinical successful
17.	Del Pizzo et al.	1996	89 % were satisfied with procedure
			95 % Could perform occasional strenuous activities; none continuous
			They all returned to their previous activity level
			Pain was improved in all patients
18.	Yoldas et al.	2003	97 % somewhat to greatly improved
			IKDC: 97 % nearly normal to normal
			Lysholm: 68 % good to excellent ratio
			SF-36: in 7 of 8 categories better than age-and sex matched population
19.	Ryu et al.		IKDC activity: 68 % nearly normal to normal. VAS, Lysholm II, Tegner score: SI
			Outerbridge grade had significant impact on outcome. 83 % overall satisfaction
20.	Hommen et al.		Lysholm, Pain, IKDC, Tegner, SF-12 score: SI. 80 % had improvement
21.	L'Insalata	1997	88 % improvement
22.	Harner	1993	100 % improvement
23.	Felix and Paulos	2002	VAS function: SI
24.	Vaquero et al.	2004	VAS pain: SI
			IKDC: 77 % nearly normal to normal

(continued)

Table 5.3 (continued)

25.	Sekiya	2006	96 % had improvement of overall function and activity level
			SF-36: PCS and MCS: higher than age- and sex- matched scores from US population
			IKDC: 80 % nearly normal to normal
26.	Sekiya	2003	IKDC: 86 % nearly normal to normal (patients with primary ACL reconstruction > revision ACL reconstruction)
			SF-36 PCS and MCS: higher than age- and sex-matched population
			KOS ADLS: 89.7 at FUT, SAS: 81 at FUT
			Lysholm: 88.4 at FUT
			93 % were somewhat to greatly improved
27.	Stone	2006	Pain score: SI of 21 %. Self-reported activity scores: SI of 10 %. Self-reported functioning scores: SI of 19 %
			IKDC, WOMAC, Tegner: SI
28.	Fukushima	2004	95 % satisfied
			95 % had disappearance of joint line pain. 72 % had disappearance of swelling
29.	Rankin	2006	Cincinnati Knee Rating System (pain, patient perception, squatting and run): SI
30.	Bhosale et al.	2007	75 % had improvement of function and pain relief at FUT
			Lysholm score: SI
			75 % was satisfied with operation
31.	Graf et al.	2004	100̈ % would recommend procedure to a friend
			88 % continue to actively participate in recreational sports
			IKDC: 50 % nearly normal to normal
32.	Rueff et al.	2006	Modified Lysholm, IKDC score, VAS pain: SI
			94 % considered their surgery to be a success and would undergo the procedure again given the same situation
33.	Von Lewinski et al.	2007	KOOS at FUT: mean value of 74 points
			Lysholm score: mean value of 74 points at FUT
34.	Dienst and Kohn		Joint function and pain reduction: SI

SI significant improvement from preoperatively to follow-up, *FUT* follow-up time

Table 5.4 Objective clinical scoring summary

Nr	Authors	Years	Clinical examination scoring
1.	Groff et al.	2001	91 % no effusion
			mean passive flexion: 129°, NS loss of motion
			side-to side difference in laxity: NS
			0 % had joint line tenderness
			Single leg vertical jump 93 % in comparison to noninvolved limp
			Hop test: 95 % in comparison to noninvolved limp
2.	Noyes and Barber-Westin	2004	3 % had signs of a meniscal tear
			97 % had no tibiofemoral joint-line pain
			89 % had a no effusion
			95 % normal antero-posterior stability
3.	Heckmann et al.	2006	74 % had disappearance of pain at tibiofemoral compartment
4.	Stollsteimer et al.	2000	No patient had loss of motion
5.	Van Arkel et al.	2000	20 % of patients had improvement in stability
6.		2002	20 % of patients had improvement in stability: SI
7.	Verdonk et al.	2005	HSS pain and function: SI
8.		2006	HSS pain score: SI (MMT + HTO group > MMT group)
			HSS walking score: SI
			HSS stair climbing ability score: SI
9.	Cole et al.	2006	IKDC knee examination: 90 % nearly normal to normal at FUT
10.	Rodeo et al.	2001	
11.	Yoldas et al.	2003	81 % no effusion
			100 % no joint line tenderness
			Average flexion at FUT = 129° Average extension at FUT: 2°
			97 % had negative to 1 + Lachmann and pivot shift test at FUT
			vertic jump + hop tests: 85 % compared to contralateral knee
			KT 1000: average side to side difference of 2 mm translation
12.	Hommen et al.	2007	IKDC: 40 % nearly normal to normal

(continued)

Table 5.4 (continued)

Nr	Authors	Years	Clinical examination scoring
13.	Sekiya et al.	2006	IKDC ROM: 31 % nearly normal to normal
			IKDC ligament examination: 94 % nearly normal to normal
			Average loss of flexion compared with non-involved knee: 10°; extension: 4°
			Bony fixation has significant better motion than suture Group
			Single leg hop and vertical jump: 91 % and 85 % of the non-involved leg
14.	Sekiya et al.	2003	IKDC laxity: 92 % nearly normal to normal
			KT-1000: average increase in AP translation of 1.5 mm to contralateral knee
			IKDC ROM: 67 % nearly normal to normal
			Single leg hop and vertical jump: 83 % and 82 % of the non-involved leg
15.	Fukushima et al.	2004	Average ROM + 7° at FUT
16.	Graf et al.	2004	IKDC ROM: 100 % nearly normal to normal
			IKDC ligament examination: 75 % nearly normal to normal
			IKDC compartmental findings: 63 % nearly normal to normal
			IKDC functional test: 75 % nearly normal to normal
			Average loss of motion: 2.3°, average loss of flexion: 4.9°
17.	Von Lewinski et al.	2007	IKDC overall: 40 % nearly normal to normal

FUT follow-up time, *NS* non-significant

5.2.2.2 Radiological Examination

Joint space narrowing indicating cartilage degeneration was observed in a number of patients and tended to increase with a longer duration of follow-up. However, a significant number of patients showed no signs of progression. Based on these limited data, meniscus allograft transplantation is believed to have a chondro-protective effect in 30–40 % of patients. However, the majority of patients are on the 'slippery slope of osteoarthritis' and will further deteriorate over time. It is unknown whether allograft transplantation delays the natural course of osteoarthritis after meniscectomy. Future research is mandatory to determine the chondroprotective power of meniscus allograft transplantation (Table 5.5).

5.2.2.3 MRI Analysis

Routine preoperative MRI may be useful for documentation of articular cartilage defects, subchondral bone status, and any remaining meniscus. Potter et al. [13] demonstrated that MRI provides accurate assessment of meniscal position, horn

Table 5.5 Radiological evaluation

Nr.	Author	Years	FUT (years)	Joint-space narrowing (mean)	Fairbank (average)	IKDC radiological evaluation
1.	Carter et al.	1999	2.9	Progression in 4 %	NA	NA
2.	Garrett et al.	1993	2–3.7	NS	NA	NA
3.	Groff et al.	2001	3.8	NS	NA	NA
4.	Wirth et al.	2002	3 and 14	Increased degenerative changes in all patients	Preoperatively: 0.7. At 3 years: 1.4. At 14 years: 2.5	NA
5.	Noyes et al.	2004	3.3	Progression in 8 %	NA	NA
6.	Rath et al.	2001	4.5	NS	NA	NA
7.	Stollsteimer et al.	2000	3.3	0.88 mm	NA	NA
8.	Verdonk et al.	2006	12.1	Progression in 48 %	Stable in 28 %	NA
9.	Yoldas et al.	2003	2.9	NS increase in joint-space width!	NA	NA
10.	Ryu et al.	2002	2.8	No change in 63 %, 1–3 mm in 25 %, >3 mm in 12.5 %	NA	NA
11.	Hommen et al.	2007	11.7	Progression in 67 %. Mean: 1.15 mm	Progression in 80 %. Mean of 0.8 mm of progression from 0.5 to 1.3	NA
12.	Vaquero et al.	2003	>1	NS	NA	NA
13.	Sekiya et al.	2003	2.8	NS	NA	48 % nearly normal to normal

(continued)

Table 5.5 (continued)

Nr.	Author	Years	FUT (years)	Joint-space narrowing (mean)	Fairbank (average)	IKDC radiological evaluation
14.		2006	3.3	NS	NA	50 % nearly normal to normal
15.	Graf et al.	2004	9.7	Progression in 75 %. Mean of 0,38 mm	NA	12.5 % nearly normal to normal (=same as preoperatively)
16.	Von Lewinski et al.	2007	20	Kellgren-Lawrence score: mean of 2.4	NA	40 % nearly normal to normal
17.	Barrett et al.	1996	5	NS	NA	NA

FUT follow-up time, *NS* not significant
Fairbank changes
Average = zo berekend
Kellgren-Lawrence radiographic grading scale of osteoarthritis of the tibiofemoral joint 0: No radiographic findings of osteoarthritis, 1: Minute osteophytes of doubtful clinical significance, 2: Definite osteophytes with unimpaired joint space, 3: Definite osteophytes with moderate joint space narrowing, 4: Definite osteophytes with severe joint space narrowing and subchondral sclerosis

and capsular attachments, meniscal degeneration and adjacent articular cartilage. It correlates well with arthroscopic evaluation of the transplant and is noninvasive. The development of dynamic and weightbearing MRI shows promise for its use in meniscal transplant analysis (Table 5.6).

In order to overcome the observed discrepancy between clinical outcome and meniscal allograft status and to assess any progression of degenerative articular changes after this type of surgery, objective outcome measures such as MRI have to be included in outcome studies. Only limited literature data are available reporting that meniscal allografting halts or slows down further degeneration [14–17]. In one recent long-term study progression of cartilage degeneration according to MRI and radiological criteria was halted in 35 % of patients, indicating a potential chondroprotective effect [18]. A recent controlled large animal study also confirmed this chondroprotective effect [19]. These data could support the use of prophylactic meniscal transplantation in meniscectomized patients without clinical symptoms, thus potentially limiting secondary cartilage degeneration. Further prospective comparative studies are mandatory to test this hypothesis.

Using MRI, meniscal allograft extrusion has been described independent of the surgical fixation technique. In our experience, using soft-tissue fixation, extrusion is observed in the corpus and anterior horn of the lateral graft, while the posterior horn is most frequently within normal values [18]. This extrusion could reduce the functional surface of the graft and thus potentially also its biomechanical function. Biological reasons for the observed extrusion posttransplantation could include progressive stretch and failure of the circumferential collagen bundle due to insufficient repair potential or increased catabolism. Future research should focus on the biology involved in ongoing metabolic and cellular processes after transplantation.

Lyophilized allografts showed more shrinkage and degeneration, indicated by altered signal intensity, than did other grafts. Therefore, this preservation technique is no longer used. In the long term, all allograft types show some shrinkage. The exact meaning of the observed shrinkage has yet to be determined. Possible hypotheses are tissue loss due to mechanical wear or a biological process of contraction often observed in scar tissue formation and healing.

In general, healing of the allograft to the rim is observed in the vast majority of patients. The meniscus allograft signal is most frequently abnormal with a more greyish appearance. The authors believe that this change in signal reflects biological remodeling of the extracellular matrix of the allograft, rather than true degenerative changes.

5.2.2.4 Second-Look Arthroscopy

Some authors have demonstrated that clinical evaluation only based on symptoms and physical examination does not allow reliable assessment of the status of the meniscus. Arthroscopic evaluation, however, should not be used as a routine postoperative evaluation tool. Most frequently, it is performed upon clinical suspicion of an intra-articular problem. In some cases, arthroscopic evaluation can be performed in association with another procedure around the knee (Table 5.7).

In general, and in accordance with the MRI evaluation, good healing of the allograft to the rim is observed in the vast majority of patients. Tearing and shrinkage can be present. The status of the allograft, however, correlates poorly with the clinical outcome.

5.3 Failures and Survival Analysis

In the literature, no consensus exists on the criteria for failure or success. A number of authors use the clinical outcome, while others propose more objective outcome parameters such as MRI or second-look arthroscopy. In general, using objective parameters, the clinical success rate is higher than estimated. In the majority of studies, a clinical success rate of 70 % and higher has been reported at the final follow-up. Because the success rate has a tendency to decrease over time, it would be preferable to use survivorship analysis rather than failure rate to describe the success of such a procedure. A survivorship is much more powerful to describe the results irrespective of the duration of follow-up. We all are aware that nothing ruins good results more than a long-term follow-up… (Table 5.8).

Based on the available survivorship data, a clinical survivorship of 70 % at 10 years can be anticipated for both medial and lateral allografts. Ligament instability, axial malalignment and cartilage degeneration are considered by most authors to be associated with a higher failure rate and inferior results, although some authors have reported satisfactory results in degenerative knees.

5.4 Conclusion

In conclusion, ample evidence has been presented to support meniscus allograft transplantation in meniscectomized painful knees, with observance of the proper indications. Significant relief of pain and improvement in function have been achieved in a high percentage of patients. These improvements appear to be long-lasting in 70 % of patients. Based on plain radiology and MRI, a subset of patients does not show further cartilage degeneration, indicating a potential chondroprotective effect. The lack of a conservatively treated control group is considered a fundamental flaw in the reported studies, making it difficult to establish the true chondroprotective effect of this type of treatment.

Based on the presented results, meniscus allograft transplantation should no longer be considered experimental surgery for the meniscectomized painful knee.

Table 5.6 MRI Analysis

Nr.	Author	Years	FUT (years)	MRI
1.	Wirth et al.	2002	14	*Deep-frozen allografts*
				– showed good preservation, no reduction in size, homogenous signal
				– showed chondromalacia grade 2
				Lyophilized allografts
				– were reduced in size, had altered signal intensity (=degeneration)
				– showed chondromalacia grade 2 in 16 %, grade 3 in 67 % and grade 4 in 16 %
2.	Noyes et al.	2004	3.3	In the coronal plane:
				– mean displacement: 2.2 mm
				– 59 % of the allografts had no displacement
				Intrameniscal signal intensity: 4 % normal, 46 % grade 1, 39 % grade 2, 11 % grade 3
3.	Stollsteimer et al.	2000	2	42 % had an abnormal mri signal, but no tear
				Average size of meniscus was 62 % of the normal meniscus (graft shrinkage)
				9 % had 1 mm extrusion
4.	Van Arkel et al.	2000	2.7	63 % completely healed to the capsule, 26 % partially detached, 11 % total detached
				21 % showed severe shrinkage, 21 % moderate shrinkage
				0 % had a normal position: 11 % bucket-handle-like configuration, 32 % extrusion, 58 % subextrusion

(continued)

Table 5.6 (continued)

Nr.	Author	Years	FUT (years)	MRI
5.	Verdonk et al.	2006	12	No progression of cartilage degeneration in 35 %
				No changes in signal intensity of the allograft: in 82 %
				No change in graft position in 35 %
				Tear observed in 12 %
6.		2004	1	The lateral transplanted meniscus is more extruded in comparison to the normal lateral meniscus.; The anterior horn (mean 5.8 mm) seems to be more extruded than the posterior horn (mean 2.7 mm)
7.	Hommen et al.	2007	11.7	71 % had grade 3 signal intensities
				57 % had moderately truncated mid-zones; 29 % had moderately diminutive anterior horns, 14 % had a severely truncated mid zone
				100 % moderate graft shrinkage
				Cartilage classification: 14 % normal, 29 % mild, 43 % moderate and 14 % severe
8.	Vaquero et al.	2003	>1	5 % changes in signal intensity
9.	Potter et al.	1996	1	– 63 % showed increased signal intensity in the posterior horn tibial attachment (=degenerative changes)
				– moderate (4) or severe (11) chondral degeneration in 63 %
				– 46 % showed peripheral displacement
				– Fragmentation (21 %) and frank extrusion (12.5 %) were associated with full-thickness chondral loss
10.	Rankin et al.	2006	2	– the mean height and width of the anterior and posterior horns were similar to native menisci
				– MRI under weight-bearing conditions
				– The anterior horn of the native meniscus moved a mean of 5 mm compared to allograft
				– Signal intensity: 25 % grade 1, 50 % grade 2, 25 % grade 3

(continued)

Table 5.6 (continued)

Nr.	Author	Years	FUT (years)	MRI
11.	Bhosale et al.	2007	1	Good integration in all, no rejection
				Mild extrusion in 20 %
				63 % wedge shaped, 25 % flat, 12 % expansion
				50 % had blurred surface
				100 % had increased signal intensity
12.	Von Lewinski et al.	2007	20	Transplants showed shrinkage, degenerative changes
				17 % subluxation
				Osteophytes

Stoller et al. classification Grade 1 represented a nonarticular focal or globular intrasubstance focus of increased signal, *grade 2* represented linear focus of intrasubstance increased signal that extended from the capsular periphery of the meniscus but did not involve an articular meniscal surface, and *grade 3* represented an area of increased signal intensity that communicated or extended to at least 1 articular surface

Extrusion of the allograft the portion of the allograft that was displaced completely over the peripheral border of the tibial plateau

Subextrusion portion of the allograft that was displaced partially over the peripheral border of the tibial plateau

Table 5.7 Evaluation by second-look arthroscopy

Nr.	Author	Years	FUT (years)	
1.	Cameron et al.	1997	2.5	77 % complete healing, 23 % failed healing, 0 % shrinkage, 60 % postop. Posterior horn tear
2.	Carter et al.	1999	2.8	18 % failed healing, 14 % shrinkage
				9 % arthritis progression
3.	Garrett et al.	1993	2	71 % complete healing
4.	Goble et al.	1999	2	72 % intact
5.	Wirth et al.	2002	3.8	– deepfrozen: 40 % shrinkage, 100 % complete healing.
				– lyophilized: 14 % incomplete healing/detachment and 93 % showed shrinkage
				– 91 % complete healing
6.	Noyes et al.	1998	1.3	8 % complete healing, 31 % partial healing, 57 % failed healing
				29 % showed degeneration/tears
7.		2004	3.3	56 % failed healing/degeneration/tears
				Articular cartilage: 85 % abnormal
8.	Rath et al.	2001	2.6	100 % complete healing
				80 % had degeneration/tears
				Arthroscopy was only performed in case of symptoms
9.	Stollsteimer et al.	2000	3.3	4 % loosening
10.	Van Arkel et al.	2000	2.7	79 % complete healing, 16 % partial healing, 5 % failed healing
				58 % subextrusion, 11 %extrusion, 11 % bucket-handle
				21 % shrinkage
				Articular cartilage: 50 % grade 3, 38 % grade 3–4, 12, 5 % grade 4 outerbridge
11.	Verdonk et al.	2005	7.2	Menisci with poor function or persist pain had severe allograft degeneration or allograft detachment
12.	Shelton and Dukes	1994	NA	100 % complete healing
13.	Veltri et al.	1994	0.5	71 % complete healing, 29 % partial healing
				14 % showed degeneration

(continued)

Table 5.7 (continued)

Nr.	Author	Years	FUT (years)	
14.	Del Pizzo et al.	1996	3.2	100 % showed complete healing
				6 % showed tear
15.	Yoldas et al.	2003	0.5–1	100 % complete healing
				33 % radial tear <1 cm
16.	Ryu et al.	2002	2.75	50 % complete healing
				20 % degeneration/tear
17.	Cryolife	1997	7	91 % fully intact in bone block cases
18.	Vaquero et al.	2003	>1	20 % shrinkage
				20 % loosening
19.	Potter et al.	1996	1	58 % subextrusion, 16 % extrusion
				26 % degeneration (fragmentation)
				Only patients with frank displacement on MRI were confirmed at arthroscopic evaluation
				52 % focal synovitis at the peripheral capsular attachment
				All areas that were seen as moderate-to-fullthickness chondral degeneration, were confirmed on arthroscopy as OB grade 3–4 change
20.	Stone et al.	2006	5.8	21 % torn menisci
21.	Bhosale et al.	2007	1	100 % complete healing
				12,5 % meniscus thinning
				25 % mild synovitis
22.	Graf et al.	2004	4	100 % complete healing
				33 % had a tear
				loose body removal in one case
				100 % well-vascularized
				No progression of degenerative changes

Table 5.8 Failure criteria and failure rate

Nr.	Author	Years	Rehabilitation program
1.	Cameron et al.	1997	Week 1–3: immobilization
			Week 3–6: progressive ROM (first 6 weeks nwb)
			From week 6: quadriceps and hamstrings exercises
2.	Groff et al.	2001	First week: pwb (crutches) with immobilization in extension-brace; cpm machine for 3 weeks; full extension at one week
			Second week: passive and active ROM of 0–90°; brace unlocked; weight-bearing as tolerated
			Week 4–6: 90°, crutches discontinued
			From week 6: closed chain exercises
			From week 8: low-impact sports
			Rehabilitation of 2–3 months
			Return to strenuous work at 3–4 months, to running at 4–5 months
			Return to strenuous sports not encouraged
3.	Wirth et al.	2002	Immediately after surgery: CPM and physical therapy
			Week 1–12: rehabilitation program
			Week 13: fwb
4.	Noyes et al.	2004	Immediately postoperative: long leg brace for 8 weeks; ROM 0–90° exercises from the first day; flexibility and quadriceps exercises
			Flexion increased every week by 10° to allow 135° after week 4
			Week 1–2: only toe-touch wb, increased to 50 % wb after week 4
			Week 6: fwb; balance, proprioception and closed chain exercises
			Week 8: stationary cycling with low resistance
			Week 9–12: swimming and walking programs
			After 12 months: light recreational sports
			Advised to never return to high-impact strenuous athletics again
			If PCL reconstruction: restricted in flexion and wb for 8 weeks
			If ACL reconstruction: other protocol
			Bledsoe Thruster brace when abnormal articular cartilage
5.	Rath et al.	2001	From day 1: quadriceps and hamstrings exercises, limited ROM 0–90°
			Week 1–4: nwb
			Week 4–6: pwb
			6–9 months: full activity
			Never aggressive cutting sports or distance running again

(continued)

Table 5.8 (continued)

Nr.	Author	Years	Rehabilitation program
6.	Stollsteimer et al.	2000	Immediately postoperatively: full ROM exercises
			Week 1–6: no fwb
			jogging at 3 months, sports at 6 months
7.	Verdonk et al.	2005	Week 1–3: nwb with ROM flexion to max 60°
			Week 3–6: ROM 0–90° + pwb
			From week 6: walk with 1 crutch
8.		2006	Week 1–3: nwb with ROM flexion to max 60°
			Week 3–6: ROM 0–90° + pwb
			From week 6: walk with 1 crutch
9.	Shelton and Dukes	1994	Immediately postoperative: full ROM, nwb till week 6
			From day 1: quadriceps and hamstrings exercises
			Week 6: fwb
			6 months: return to sports if knee is fully rehabilitated
10.	Veltri et al.	1994	Week 1–6: pwb + ROM exercises in hinged brace
			After week 6 fwb as tolerated
11.	Cole et al.	2006	Immediately postoperative: wb as tolerated with crutches + hinged brace + immediate active and passive ROM without limitation
			Week 1–6: flexion wb < 90° restricted
			After week 6: no brace + ROM as tolerated
			After 12 weeks: jogging allowed with progression to running and sport-specific-type drills
12.	Yoldas et al.	2003	Immediately postoperative: quadriceps sets and straight leg raises
			Day 1: start passive ROM with CPM, for 1 month
			Week 1: full extension, pwb, brace locked in extension
			From week 2: wb as tolerated
			Week 4–6: 90° flexion, fwb, closed chain exercises
			Rehabilitation of 2–3 months
13.	Ryu et al.	2002	Immobilization in full extension with progressive wb over 4–5 weeks
			Week 1–4: ROM 0–90°
			From week 5: gradual increase in flexion of 10–15° each week
			If concomitant ACL reconstruction: ACL protocol was subordinated to meniscal allografts requirements

(continued)

Table 5.8 (continued)

Nr.	Author	Years	Rehabilitation program
14.	Hommen et al.	2007	Immediately postoperative: quadriceps sets en straight leg raising
			24 h after surgery CPM till 1 month
15.	Felix and Paulos	2002	Postoperatively braced in extension. Plantar touch wb
			Week 3: 60° flexion
			Week 4: progressive wb increased by 25 % every week
			Week 6: full flexion
			Week 7–8: fwb
			6–9 months: full activities and sports
16.	Sekiya et al.	2003	Immediately postoperative: exercises, pwb with crutches, brace locked in full extension
			Day 1: cpm
			Week 1: full extension
			Week 2: wb as tolerated, sedentary work
			Week 4–6: 90° flexion, stop crutches
			From week 6: close chain exercises
			strenuous work and running after 5–6 months—sports after 6–9 months
17.		2006	Immediately postoperative: exercises, pwb with crutches, brace locked in full extension
			Day 1: cpm
			Week 1: full extension
			Week 2: wb as tolerated, sedentary work
			Week 4–6: 90° flexion, stop crutches
			From week 6: close chain exercises
			strenuous work and running after 5–6 months—sports after 6–9 months
18.	Stone et al.	2006	Week 1–4: MAXIMAL PROTECTIVE PHASE = pwb (week 1 and 2: 10 and 20 % toe touch), extension-locked hinged brace, passive and active ROM, daily icing and elevation, straight leg exercises, manually resisted hip, foot and ankle exercises, pool workouts, soft-tissue treatments, a trunk stabilization program, nwb aerobic exercises
			Week 4–12: MODERATE PROTECTIVE PHASE = stretching, manual treatments to restore ROM, 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
			No resisted leg extension machines, no high-impact, cutting, or twisting activities for at least 4 months postoperatively

(continued)

Table 5.8 (continued)

Nr.	Author	Years	Rehabilitation program
19.	Fukushima et al.	2004	24-48 h postoperative: start ROM exercises
			Week 1–4: nwb
			Week 5: pwb 50 %
			Week 6: fwb + Flexion > 90° allowed
			Week 8–10: Closed chain exercises
			Never strenuous/contact/rotational sports in the future
20.	Rankin et al.	2006	Postoperatively: long leg brace for 6 weeks, ROM 0–90°, toe-touch wb first 2 weeks, flexibility and quadriceps strengthening exercises
			Week 3–4: flexion to 120°, 50 % wb
			Week 5–6: ROM 0°–135° at 4 weeks
			Week 6: fwb + balance, Proprioception, closed kinetic chain exercises
			Week 7–8: stationary cycling
			Week 9–12: start swimming and walking
			12 Months: light recreational sports
			Never high-impact activities/strenuous athletics again
21.	Bhosale et al.	2007	The Oscell Rehabilitation for ACI procedure and limit of knee flexion to 45° for 3 weeks
			Week 12: fwb
22.	Graf et al.	2004	Week 1–2: nwb, light resistive isometric exercises, medial unloading brace 10–90° (if + ACL reconstruction: derotational brace), stationary biking when 90° was obtained
			Week 2–4: pwb
			Week 5: fwb
			Week 6: resistance exercises
			3 months: advancement in rehabilitation exercises and strengthening programs
			6 months: stop bracing, start straight line jogging (without cutting and pivoting)
			8 months: start agility exercises
			1 year: sporting activities (never high-impact, running, jumping, twisting or turning sports again)
23.	Rueff et al.	2006	Week 1–6: ROM limited to 0–90°
			Early wb

(continued)

Table 5.8 (continued)

Nr.	Author	Years	Rehabilitation program
24.	Von Lewinski et al.	2007	Postoperatively: strengthening exercises for quadriceps muscle, brace with limited ROM for 12 weeks
			Week 1–6: ROM 30–60°
			Week 6–12: ROM 20–90°
			Week 1–12: pwb 10 kg
25.	Dienst and Kohn		Postoperatively: ROM 0–90° active + passive exercises, pwb with brace locked in extension for 6 weeks
			3 months: now full squat allowed
			1 year: sport activities allowed

ROM range of motion
nwb non-weight bearing
cpm continuous passive motion
pwb partial weight-bearing
fwb full weight bearing
wb weight bearing
The Oscell rehabilitation for ACI procedure

References

1. Cameron JC, Saha S (1997) Meniscal allograft transplantation for unicompartmental arthritis of the knee. Clin Orthop 337:164–171
2. Noyes FR, Barber-Westin SD (1995) Irradiated meniscus allografts in the human knee: a two to five year follow-up study. Orthop Trans 19:417
3. Verdonk PCM, Demurie A, Almqvist KF, Veys EM, Verbruggen, Verdonk R (2005) Transplantation of viable meniscal allograft: survivorship analysis and clinical outcome of one hundred cases. J Bone Joint Surg Am 87:715–724
4. Ryu RK, Dunbar VWH, Morse GG (2002) Meniscal allograft replacement: a 1-year to 6-year experience. Arthroscopy 18:989–994
5. Stone KR, Walgenbach AW, Turek TJ, Freyer A, Hill MD (2006) Meniscus allograft survival in patients with moderate to severe unicompartmental arthritis: a 2- to 7-year follow-up. Arthroscopy 22(5):469–478
6. Bhosale AM, Myint P, Roberts S, Menage J, Harrison P, Ashton B, Smith T, McCall I, Richardson JB (2007) Combined autologous chondrocyte implantation and allogenic meniscus transplantation: a biological knee replacement. Knee 14(5):361–368
7. Walker PS, Erkman MJ (1975) The role of the menisci in force transmission across the knee. Clin Orthop 109:184–192
8. Johnson DL, Bealle D (1999) Meniscal allograft transplantation. Clin Sports Med 18:93–108
9. Cole BJ, Carter TR, Rodeo SA (2003) Allograft meniscal transplantation: background, techniques, and results. Instr Course Lect 52:383–396
10. Rodeo SA (2001) Meniscal allografts—where do we stand? Am J Sports Med 29:246–261
11. Cole BJ, Cohen B (2000) Chondral injuries of the knee. A contemporary view of cartilage restoration. Orthop Spec Ed 6:71–76
12. Rijk PC (2004) Meniscal allograft transplantation—part i: background, results, graft selection and preservation, and surgical considerations. Arthroscopy 20:728–743

13. Potter HG, Rodeo SA, Wickiewicz TL et al (1996) MR imaging of meniscal allografts: correlation with clinical and arthroscopic outcomes. Radiology 198:509–514
14. Zukor DJ, Cameron JC, Brooks PJ et al (1990) The fate of human meniscal allografts. In: Ewing JW (ed) Articular cartilage and knee joint function. Raven, New York, pp 147–152
15. Garrett JC (1993) Meniscal transplantation: a review of 43 cases with 2- to 7- year follow-up. Sports Med Arthrosc Rev 1:164–167
16. Kuhn JE, Wojtys EM (1996) Allograft meniscal transplantation. Clin Sports Med 15:537–556
17. Stollsteimer GT, Shelton WR, Dukes A, Bomboy AL (2000) Meniscal allograft transplantation: a 1-to-5 year follow-up of 22 patients. Arthroscopy 16:343–347
18. Verdonk PCM, Demurie A, Almqvist KF, Veys EM, Verbruggen G, Verdonk R (2006) Transplantation of viable meniscal allograft. J Bone Joint Surg Am 88(1 Suppl 1):109–118
19. Aagaard H, Jorgensen U, Bojsen-Moller F (2003) Immediate versus delayed meniscal allograft transplantation in sheep. Clin Orthop 406:218–227