Original Article

Clinical Evaluation of Arthroscopic-assisted Allograft Meniscal Transplantation

Haw Chong Chang,[1] *FRCSEd (Orth), M Med (Surg), FRCS (Edin & Glas)*, Kai Lin Teh,[2] Kah Lai Leong,[2] Su Lian Mak,[2] Sarina Abdul Karim,[1] *RN*

Abstract

Introduction: A meniscal deficient knee is at risk of early degenerative osteoarthritis. Allograft meniscal transplantation has been used to treat the meniscus deficiency to alleviate pain symptoms and to delay progression to arthritis. This case series aims to assess the postoperative outcomes of patients who have undergone meniscal allograft transplantation in our hospital. Materials and Methods: This is a prospective clinical review of prospectively collected data of our Meniscal Transplantation Programme from 2004 to 2007. Twelve meniscal allografts were implanted in 12 males with symptomatic knees, using arthroscopically assisted techniques. Preoperative and postoperative assessments were conducted using the Visual Analogue Scale (VAS), Tegner Activity Level Scale, Lysholm Knee Scoring Scale, and 2000 International Knee Documentation Committee (IKDC) scoring systems. Results: The mean age was 26.7 years with a mean follow-up of 17 months (range, 5 to 37). The VAS score for pain improved from 5.5 (3-10) to 1.4 (0-2) [*P* <0.05], Tegner from 3 (2-5) to 5.9 (3-9) [*P* <0.05], Lysholm from 62.5 (27-88) to 88.6 (70-100) [*P* <0.05], IKDC Subjective Score from 50 (24-79) to 79.5 (56-95) [*P* <0.05]. Overall IKDC Knee Examination Grades revealed 10 nearly normal and 2 abnormal scores. Conclusions: This is the first series of allograft meniscal transplantation from Southeast Asia. Patient outcome evaluation via VAS, Tegner Activity Level Scale, Lysholm Knee Scoring Scale and 2000 IKDC Knee Evaluation Form showed improvement in symptoms and knee function after implantation.

Ann Acad Med Singapore 2008;37:266-72

Key words: Meniscus allograft, Outcome, Transplantation

Introduction

The menisci of the knee are fibro-cartilaginous structures essential for the normal biomechanic of the knee joint.[1,2] They play a critical role in shock absorption, load-transmission, joint lubrication and congruency, nutrition, stability of the knee and facilitating the rotation of the opposing articular surfaces of the joint.[3-5]

In 1948, Fairbank[2] first demonstrated radiographic evidence of cartilage degeneration in the knee following both medial and lateral meniscectomies, emphasising the importance of the menisci in force-transmission across the knee joint. Orthopaedists have since made continuing efforts to preserve the injured meniscal tissue wherever feasible, by means of repair, excision and replacement.[6,7]

The first meniscal allograft transplantation in humans was performed by Milachowski and Wirth in 1984.[8] Since then, the literature has shown evidence attesting to the benefits of meniscal allograft transplantation in improving knee function and pain.[7,9-18]

Meniscus transplantation remains an uncommon procedure in our country and the rest of Southeast Asia. Some of the reasons include lack of meniscus allograft availability from local tissue banks, lack of surgical expertise and equipment as well as the high cost of meniscus allografts sourced from overseas.

This prospective clinical review seeks to assess the early postoperative outcomes of consecutive patients who underwent meniscal allograft transplantation by a single surgeon (first author) in our institution between 2004 and 2007.

[1] Department of Orthopaedic Surgery, Changi General Hospital, Singapore
[2] Faculty of Medicine, Yong Loo Lin School of Medicine, National University of Singapore, Singapore
Address for Correspondence: Dr Chang Haw Chong, HC Chang Orthopaedic Surgery Pte Ltd, 6 Napier Road, #04-06 Gleneagles Medical Centre, Singapore 258499.
Email: hcchang@ortho.com.sg

Materials and Methods

Between November 2004 and June 2007, 12 meniscal allograft transplantations were performed in 12 male patients. The meniscal allografts were sourced from CryoLife Inc (Kennesaw, GA, USA) which is a tissue bank accredited with the American Association of Tissue Banking (AATB) and registered with the US Food and Drug Administration (FDA). These meniscal allografts were cryopreserved with the theoretical advantage of cell survival in the graft. Allograft size matching was done using plain antero-posterior and lateral radiographs of the knee with a standard diameter metallic disc as a magnification marker. Successful size matching of meniscal allografts varied from 2 months to 1 year depending on availability.

All the procedures were performed using arthroscopically assisted techniques. There were 5 medial and 7 lateral menisci implanted in 7 right and 5 left knees. The mean age was 26.7 years (range, 20 to 51) with a mean follow-up of 17 months (range, 5 to 37). Patients averaged 1.5 surgical procedures (range, 0 to 4) prior to transplantation. Eight patients underwent isolated meniscal transplantation while the remaining 4 underwent concomitant procedures (Table 1). The mean duration of surgery was 179 ± 35 minutes (range, 125 to 250). In the 8 patients who underwent isolated meniscal transplantation, the mean duration of surgery was 162 ± 25 minutes (range, 125 to 195).

Indications for Meniscus Transplantation

A pre-requisite for successful meniscal allograft surgery is careful patient selection using history, physical examination and imaging techniques such as radiographs and magnetic resonance imaging. In this series, the selection criteria for meniscus transplant included:

1. Joint line pain attributed to lack of meniscus
2. Articular cartilage chondrosis of Outerbridge[19] grade II or less
3. Joint stability
4. Normal mechanical alignment

Mechanical alignment was assessed clinically and also through the use of long leg standing films from the hips to the ankles where necessary. Occasionally, radionuclide bone scans were ordered to assess for increased uptake in the subchondral bone of the meniscectomised compartment of the knee (Fig. 1) in patients with equivocal pain symptoms. Articular cartilage changes in the affected compartment should generally not be worse than Outerbridge grade II. Of the 12 patients, 3 had Outerbridge grade I chondrosis, 8 had Outerbridge grade II chondrosis while 1 patient had focal Outerbridge grade III chondrosis of less than 1.5 cm diameter (patient 9, Table 1).

Table 1. Patient History, Indications for Transplantation and Surgery Performed

No.	Age	History	Cartilage status	Indication	Surgery
1	38	Locked knee from irreparable displaced bucket handle LM tear with ACL tear. Underwent subtotal lateral meniscectomy.	OB II	Knee pain with instability	LM allograft with allograft ACL reconstruction
2	32	ACL reconstruction with medial meniscectomy.	OB I	Post meniscectomy pain	MM allograft
3	20	Subtotal lateral meniscectomy for torn discoid LM, ACL intact.	OB II	Post meniscectomy pain	LM allograft
4	23	Lateral meniscectomy for torn LM, ACL intact.	OB II	Post meniscectomy pain	LM allograft
5	22	ACL reconstruction with medial meniscectomy.	OB II	Post meniscectomy pain	MM allograft
6	20	ACL reconstruction with lateral meniscectomy.	OB II	Post meniscectomy pain	LM allograft
7	24	Subtotal lateral meniscectomy for torn discoid LM, ACL intact.	OB I	Post meniscectomy pain	LM allograft
8	21	Failed ACL reconstruction with meniscectomised MM.	OB II	Recurrent knee instability	MM allograft with allograft ACL revision
9	22	ACL tear with chronic displaced LM bucket handle tear.	OB III	Knee pain with instability	LM allograft with allograft ACL reconstruction
10	27	Failed ACL reconstruction & MCL repair with subtotal medial meniscectomy.	OB II	Recurrent knee instability	Stage 1: MM allograft with allograft MCL reconstruction Stage 2: Allograft ACL revision 3 months later
11	51	LM subtotal meniscectomy 30 years ago with ACI to LFC cartilage defect 1 year ago.	OB II	Post meniscectomy pain	LM allograft
12	21	Failed ACL reconstruction with meniscectomised MM.	OB I	Recurrent knee instability	MM allograft

ACI: autologous chondrocyte implantation; ACL: anterior cruciate ligament; LFC: lateral femoral condyle; LM: lateral meniscus; MM: medial meniscus; MCL: medial collateral ligament; OB: outerbridge chondrosis grade

Patients were deemed unsuitable for this procedure if they had:

1. Uncorrected axis deformity greater than 10°
2. Tricompartmental arthrosis
3. Multiple compartmental pain
4. Morbid obesity

We do not offer meniscus allograft replacement for patients without joint line pain symptoms even if they had a previous meniscectomy.

The indications for meniscal allografts as well as the patient histories and treatment rendered are summarised in Table 1. Patients who had prior meniscectomies with joint line tenderness during activities of daily living (ADL) or sports comprised the majority of the patients in this series (n = 9). The remaining 3 patients (patient no. 8, 10 and 12, Table 1) were offered this surgery as an adjunct for knee instability treatment based on the fact that the meniscus has both load distribution and stabilising functions.[20]

Patient 10 (Table 1) presented with a failed anterior cruciate ligament (ACL) reconstruction as a result of an inadequately treated medial collateral ligament deficiency. His medial meniscus was also deficient (Fig. 2). His knee was reconstructed in two stages. During the first stage, medial meniscus transplantation (Fig. 3) was performed together with medial collateral ligament reconstruction using allograft tendon. The reconstructed knee was protected in a postoperative knee brace for 3 months before the revision ACL reconstruction was performed using tendon allograft. This case offered a unique opportunity to assess the healing status of the medial meniscus allograft. The allograft was found to be completely healed to the rim and capsule and appeared to look like a native normal meniscus (Fig. 4).

Patient 11 had a history of open lateral menisectomy 30 years ago. He presented with post-menisectomy syndrome and underwent first generation autologous chondrocyte implantation (ACI) for cartilage defect for his lateral femoral condyle in another hospital. He was subsequently referred to us a year after his ACI surgery for persistent pain in the lateral knee compartment associated with effusion. Lateral meniscus allograft transplantation was performed for him with improvement in his knee symptoms.

Outcome Evaluation

Twelve implanted allografts were evaluated on follow-up for the purpose of this study. The mean follow-up duration was 17 months (range, 5 to 37).

All patients were asked to complete the Visual Analogue Scale VAS for pain, Tegner Activity Level Scale,[21] Lysholm

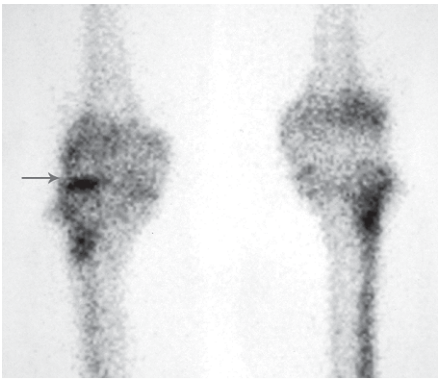

Fig. 1. Increased uptake on radionuclide bone scan in lateral compartment of right knee with previous subtotal lateral meniscectomy for patient 3 (Arrow).

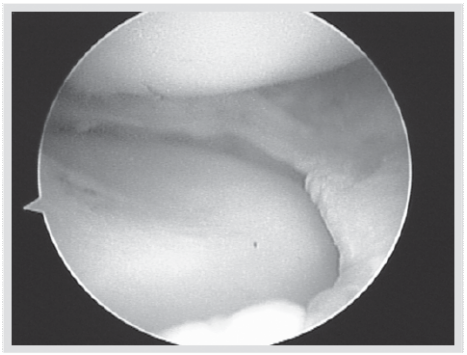

Fig. 2. Medial meniscus deficiency from chronic ACL insufficiency in patient 10.

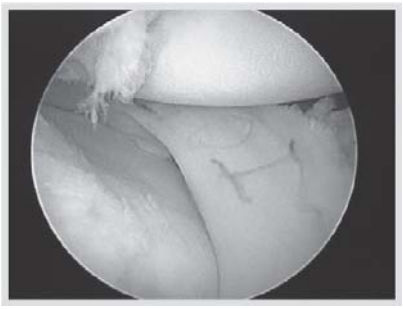

Fig. 3. The medial meniscal allograft implanted into the knee of patient 10.

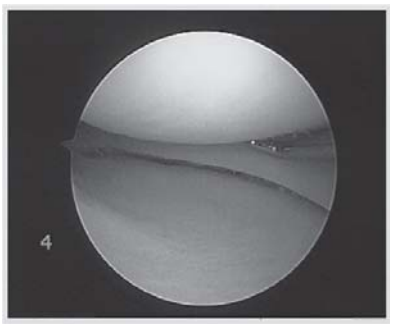

Fig. 4. Medial meniscus allograft seen at 3 months after transplantation in patient 10.

Table 2. Detailed VAS, Tegner and Lysholm Scores

No.	Follow-up (mo)	Preoperative VAS	Postoperative VAS	Preoperative Tegner	Postoperative Tegner	Preoperative Lysholm	Postoperative Lysholm
1	37	6	2	2	9	47	87
2	26	3	1	4	6	88	90
3	26	8	1	5	7	86	100
4	25	4	2	4	4	60	74
5	17	3	1	3	6	27	94
6	14	10	2	3	6	67	99
7	14	4	0	3	7	52	94
8	13	6	1	2	7	65	95
9	11	7	2	2	5	58	85
10	9	4	2	3	3	66	70
11	7	7	2	2	4	63	85
12	5	4	1	3	7	70	90
Mean		**5.5**	**1.4**	**3**	**5.9**	**62.5**	**88.6**
P		**0.002**		**0.005**		**0.002**	

VAS: Visual Analogue Scale

Table 3. Detailed IKDC Scores

No.	Follow-up (mo)	Preoperative IKDC Subjective	Postoperative IKDC Subjective	Preoperative IKDC Objective	Postoperative IKDC Objective
1	37	24.1	85.1	C	C
2	26	79.3	74.7	B	B
3	26	79.3	80.5	B	B
4	25	50.6	56.3	D	B
5	17	50.6	80.5	D	B
6	14	40.2	87.4	C	B
7	14	37.9	95.4	C	B
8	13	28.7	93.1	D	B
9	11	54	63.2	D	B
10	9	52.9	75.9	D	B
11	7	45	73.1	C	C
12	5	57.5	88.5	C	B
Mean		**50**	**79.5**		
P		**0.006**			

IKDC: International Knee Documentation Committee

Knee Scoring Scale[22] and International Knee Documentation Committee (IKDC) Subjective & Objective Knee Evaluation[23] prior to surgery.

The follow-up evaluation consisted of a review of the patients' case records and a completion of self assessment instruments including the VAS, Tegner Activity Level Scale,[21] Lysholm Knee Scoring Scale[22] and IKDC Subjective Knee Evaluation Form.[23] Subjective pain was recorded using the VAS scale. This scale ranged from 0 which is no pain to 10 which is the worst pain imaginable.

The Tegner score assessed activity levels. A level 5 activity would include heavy labour, competitive sports such as cycling, cross-country skiing and recreational sports such as jogging on uneven ground at least twice weekly. A level 6 activity would include recreational sports such as tennis, badminton, handball and jogging at least 5 times per week. In comparison, a level 2 activity would include light labour work, ability to walk on uneven ground

Table 4. Summary of Selected Clinical Outcome Studies

Study	No. grafts/ No. patients	Length of follow-up	Clinical outcomes
Milachowski[8]1989	22/22	Mean 14 months	Arthroscopy in 2/3 of the cases at mean of 8 months after operation. Both lyophilised and deep frozen transplanted menisci decreased in size. Deep frozen menisci showed better results.
Van Arkel & De Boer[15] 1995	25/23	Mean 3 years	80% successful
Noyes & Barber-Westin[13]1995	96/82	Mean 30 months (range, 22 to 58)	67 grafts in 62 patients survived at least 2 years post-op; of these, 13% healed, 45% partially healed, 47% failed, 2% unknown
Cameron & Saha[16]1997	67/63	1 to 5.5 years	87% good to excellent results
Carter[17]1999	46/46	24 to 73 months	98% pain relief; majority with improvement in activity level
Stollsteimer[11]2000	23/22	1 to 5 years	100% pain relief; overall improved function
Ryu[10]2002	26/25	1 to 6 years	Decreased pain, improved function with 65% at nearly normal activity level
Wirth[12]2002	22/22	14 years	All showed degenerative changes by radiography; no differences between transplanted versus meniscectomy control group
Verdonk[18]2006	42/41	Mean 12 years	Improvement in pain and function; overall failure rate 19%
Our study2007	12/12	Mean 17 months (range, 5 to 37)	Significant improvement in pain, Tegner, Lysholm and IKDC scores

but impossible to back pack or hike. A level 3 activity would include light labour such as nursing activities.

The Lysholm knee score was designed to document the patient's evaluation of function. An overall score of 0 to 100 points is calculated, with 95 to 100 points indicating an excellent outcome; 84 to 94 points, a good outcome; 65 to 83 points, a fair outcome; and <65 points, a poor outcome.

The patients were assessed clinically using the 2000 IKDC Knee Examination Form[23] by the surgeon and a knee function grade was obtained for each patient. The use of the IKDC evaluation form will reveal less favourable results than those evaluated with other current evaluation forms, because an existing knee problem cannot be hidden with a high numerical score that is added up from other, unrelated parameters.

Rehabilitation

In the immediate postoperative treatment, swelling in the operated knee was minimised with the use of cold compress device. A postoperative knee brace allowed controlled knee motion from full extension to 90 degrees of flexion for the first 4 weeks after meniscal allograft implantation. Our patients were advised to toe-touch weight bear on the operated leg with the use of crutches for the first 6 weeks after surgery. An early goal was to achieve full knee extension. The knee was allowed to flex beyond 90 degrees 4 weeks after the procedure. The patient was not allowed to squat or do pivoting activities for the first 3 months after the implantation. For patients with concomitant ACL reconstructions, the standard ACL rehabilitation protocol was followed except for the change in weight bearing status from immediate full weight bearing to toe-touch weight bearing for the first 6 weeks and the restriction of knee flexion beyond 90 degrees for the first 4 weeks.

Statistical Analysis

SPSS version 11.0 for Windows XP software was used for statistical analysis. The VAS, Tegner, Lysholm and IKDC-subjective scores were reported as mean values ± standard deviation (range). Comparison of preoperative and last follow-up postoperative self-reported measures taken from Tegner, Lysholm, IKDC-subjective and VAS were analysed using the Wilcoxon signed rank test. All statistical tests were 2-sided and the threshold of statistical significance was set at $P < 0.05$.

Results

None of the patients represented with torn meniscus symptoms of pain and locking or further surgery requiring resection of the transplanted meniscal allograft at the time of review. The results are summarised in Tables 2 and 3.

Pain improved preoperatively to postoperatively from VAS of 5.5 ± 2.2 (3-10) to 1.4 ± 0.7 (0-2) ($P = 0.002$). Improvement in pain symptoms was a universal finding in all patients in this series although the quantum of improvement varied among the patients.

Tegner activity level scores rose from a 3.0 ± 0.9 (2-5) preoperatively to 5.9 ± 1.7 (3-9) ($P = 0.005$) postoperatively.

Subjective knee rating based on the Lysholm and IKDC-subjective scores showed significant mean improvement from preoperatively to postoperatively. The Lysholm scores improved from 62.5 ± 16.4 (27-88) to 88.6 ± 9.2 (70-100) [$P = 0.002$]. The IKDC-subjective scores improved from 50 ± 17 (24-79) to 79.5 ± 11.7 (56-95) [$P = 0.006$].

The 2000 IKDC knee examination form was used in the assessment of all 12 patients. The overall IKDC grades determined by the worst grade of the 3 domains tested revealed 2 nearly normal (IKDC B), 5 abnormal (IKDC C) and 5 severely abnormal (IKDC D) scores prior to surgery. This improved at follow-up assessment to reveal 10 nearly normal (IKDC B) and 2 abnormal scores (IKDC C). As shown in Table 3, there were 4 patients who remained at the same knee IKDC grade while the other 8 showed improvement in IKDC grade. Five of the 8 who showed improvements in IKDC grade achieved a quantum improvement of 2 grades.

Postoperative complications, namely wound infection, recurrent meniscal tear with locking or arthrofibrosis were absent in all patients.

Discussion

To date, the literature has shown evidence of improvement in knee function and pain as the most consistent finding in meniscal allograft transplantation.[7] A summary of selected clinical outcome studies on meniscal allograft transplantation is shown in Table 4.

Milachowski et al[8] were the first to demonstrate early acceptable results in 22 meniscal transplants performed with an average follow-up duration of 14 months. Goble et al[9] studied 47 patients over a minimum follow-up period of 2 years. Pain relief and improved function were the primary benefits of their meniscal transplantations. Ryu et al[10] reported on 26 meniscal allograft transplantations with an average follow-up time of 33 months. The most significant finding was that of early pain relief and improvement in functional status. Arthroscopic evaluation in 10 of their 26 patients showed 50% normal looking grafts, 30% with graft shrinkage and 20% with recurrent tears. Stollsteimer et al[11] followed up on 22 patients who underwent meniscal transplantation with non-irradiated, cryopreserved allografts using bone plugs. The patients were evaluated at an average follow-up of 40 months postoperatively and he was able to demonstrate improvement in pain level and overall function in all patients. In Stollsteimer's study, 12 patients who had follow-up MRI showed abnormal meniscal signals in 42% and peripheral graft extrusion in 8% of those studied despite the reported improvements in pain level and knee function.

In keeping with the results of these studies, all our evaluated patients who presented with preoperative pain, locking, and instability showed symptomatic relief after the meniscal allograft transplantation, with improvement in pain and locking being the most consistent findings. Second look arthroscopy was only performed in 1 of the 12 patients in this study (patient 10), i.e., during the staged revision of his ACL. The complete healing of the meniscal allograft rim to the capsule together with the gross appearance of a "normal" looking meniscus (Fig. 4) at just 3 months post-implantation was extremely encouraging.

Long-term outcome of meniscal allograft transplantation is less clear. Milachowski's[8] series of patients were re-evaluated by Wirth et al[12] at 14 years follow-up which showed no significant differences between the transplanted group and the meniscectomised control group. All showed increased degenerative changes by radiography. Verdonk et al[18] reported their series of 100 transplants in 96 patients with a 10-year follow-up. Survival analysis showed lasting improvement in pain relief and knee function in 70% of the patients at 10 years.

In our study, all except for 1 (patient 9) had chondrosis of Outerbridge grade II or less at the time of meniscus transplantation. This indication is based on early observations of some failures in patients with advanced arthrosis.[13] Stone et al[14] recently demonstrated survival of 42 out of 47 meniscal allografts (89.4%) for 2 to 7 years after implantation into knees with moderate to severe unicompartmental arthrosis. In addition, they showed significant mean improvement in preoperative versus postoperative self-reported measures of pain, activity and knee function.

The indications for meniscal allografts transplantation continue to evolve. The use of realignment osteotomy, cartilage defect resurfacing with autologous chondrocytes has widened the role of meniscal allografts to patients with focal unicompartmental arthrosis with meniscal deficiency. An example in this series would be patient 11 who underwent prior autologous chondrocyte implantation for his lateral femoral condyle full thickness cartilage defect before having his meniscus deficiency treated with allograft transplantation. No patient in this series had serious mal-alignment in the lower limbs that required realignment osteotomy.

We recognise the inherent limitations in our study namely a small sample size of 12 patients and short duration of follow-up. The initial few patients in this series formed part of the learning curve for the surgeon. In addition, the lack of a control group made it difficult to judge the significance of the various assessment instruments. However, we felt that is was worthwhile to publish our early experience with this treatment modality for the highly select group of patients who might require them as there was no published information on meniscal transplantation from Southeast Asia.

Conclusion

This study is the first series of allograft meniscal transplantation done in Southeast Asia. This study has yielded optimistic results, which are consistent with previous

short-term follow-up literature, showing evidence of symptomatic relief and improvement in knee function following meniscal allograft transplantation. It remains to be established as to whether meniscal allograft transplantation would prove to be a durable and useful procedure in restoring the normal biomechanics in the knee joint. More long-term studies in this early-patient population would be necessary to ascertain our preliminary findings.

REFERENCES

1. Allen PR, Denham RA, Swan AV. Late degenerative changes after meniscectomy. J Bone Joint Surg Br 1984;66:666-71.
2. Fairbank TJ. Knee joint changes after meniscectomy. J Bone Joint Surg Br 1948;30:664-70.
3. Henning CE, Lynch MA. Current concepts of meniscal function and pathology. Clin Sports Med 1985;4:259-65.
4. Restrom P, Johnson RJ. Anatomy and biomechanics of the menisci. Clin Sports Med 1990;9:523-38.
5. Walker PS, Erkmann MJ. The role of the menisci in force transmission across the knee. Clin Orthop Relat Res 1975;109:184-92.
6. Cooper DE, Arnoczky SP, Warren RF. Meniscal repair. Clin Sports Med 1991;10:529-48.
7. Rodeo SA. Meniscal allografts: Where do we stand? Am J Sports Med 2001;29:246-61.
8. Milachowski KA, Weismeier K, Wirth CJ. Homologous meniscus transplantation: Experimental and clinical results. Int Orthop 1989;13: 1-11.
9. Goble E, Kane S, Wilcox T, Doucette S. Meniscal allografts. In: McGinty J, Caspari R, Jackson R, Poehling G, editors. Operative arthroscopy. 2nd ed. Philadelphia: Lippincott-Raven, 1996:317-31.
10. Ryu RK, Dunbar V WH, Morse GG. Meniscal allograft replacement: a 1-year to 6-year experience. Arthroscopy 2002;18:989-94.
11. Stollsteimer GT, Shelton WR, Dukes A, Bomboy AL. Meniscal allograft transplantation: a 1- to 5-year follow-up of 22 patients. Arthroscopy 2000;16:343-7.
12. Wirth CJ, Peters G, Milachowski KA, Weismeier KG, Kohn D. Long-term results of meniscal allograft transplantation. Am J Sports Med 2002;30:174-81.
13. Noyes FR, Barber-Westin SD. Irradiated meniscus allografts in the human knee: a two to five year follow-up study. Orthop Trans 1995;19:417.
14. 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;22:469-78.
15. Van Arkel ERA, De Boer HH. Human meniscal transplantation: preliminary results at 2 to 5-year follow-up. J Bone Joint Surg Br 1995;77:589-95.
16. Cameron JC, Saha S. Meniscal allograft transplantation for unicompartmental arthritis of the knee. Clin Orthop Relat Res 1997;337:164-71.
17. Carter TR. Meniscal allograft transplantation. Sports Med Arthrosc Rev 1999;7:51-62.
18. Verdonk PCM, Verstraete KL, Almqvist KF, De Cuyper K, Veys EM, Verbruggen G, et al. Mensical allograft transplantation: long-term clinical results with radiological and magnetic resonance imaging correlations. Knee Surg Sports Traumatol Arthrosc 2006;14:694-706.
19. Outerbridge RE. The etiology of chondromalacia patellae. J Bone Joint Surg Br 1961; 43:752-57.
20. Levy IM, Torzilli PA, Fisch ID. The contribution of the menisci to the stability of the knee. In: Mow VC, Arnoczky SP, Jackson DW, editors. Knee Meniscus: Basic and Clinical Foundations. New York: Raven, 1992:107.
21. Tegner Y, Lysholm J. Rating systems in the evaluation of knee ligament injuries. Clin Orthop Relat Res 1985;198:43-9.
22. Lysholm J, Gillquist J. Evaluation of knee ligament surgery results with special emphasis on use of a scoring scale. Am J Sports Med 1982;10:150-4.
23. Irrgang JJ, Anderson AF, Boland AL, Harner CD, Kurosaka M, Neyret P, et al. Development and validation of the international knee documentation committee subjective knee form. Am J Sports Med 2001;29:600-13.