New Technique of Arthroscopic Meniscus Repair in Radial Tears

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Contents

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Introduction

The meniscus is a fibrocartilagious tissue, which contributes to functions of load transmission, shock absorption, lubrication, and stability in the knee joint [14, 16]. These functions are important for the preservation of the articular cartilage. The meniscus often is injured by sports or daily living activities. Although some disorders of the meniscus can be treated non-operatively, others require surgery including meniscectomy or meniscal repair. The long-term consequences of a meniscectomy or even partial meniscectomy have been shown to be potentially deleterious to the joint surface [6, 13, 24, 30, 33]. After the first report of a meniscus repair by Annadale, there have been numerous studies published on the repair of meniscus [1, 4, 5, 11, 12, 18, 19, 32, 34]. The peripheral meniscal blood supply is shown to be one of the keys to the healing of the meniscus [2]. The peripheral 20–30% of the medial meniscus and the peripheral 10–25% of the lateral meniscus are vascular [2, 13], whereas the inner margin of the meniscus is the avascular zone. Tears in the avascular zone of the meniscus are thought to be not suitable for repair [7].

Radial tear that interrupts the circumferential fibers is problematic to repair because hoop strain causes separation of tear site and because this type of tear includes avascular zone of meniscus and is poor in reparative process [6, 22]. Although there are a few reports about meniscus repair for radial tears [28, 34], meniscal repair techniques can be demanding and the criteria for repair continues to be defined [7, 9, 10, 15, 17, 25, 29]. In this chapter, we describe a novel suture method for radial tear, and its preliminary results.

Methods and Patients

Classification of Radial Tear

Using standard anterolateral and anteromedial portals, the tears were assessed and classified based on its length and shape of radial tear (Fig. 1). When the tear was located in

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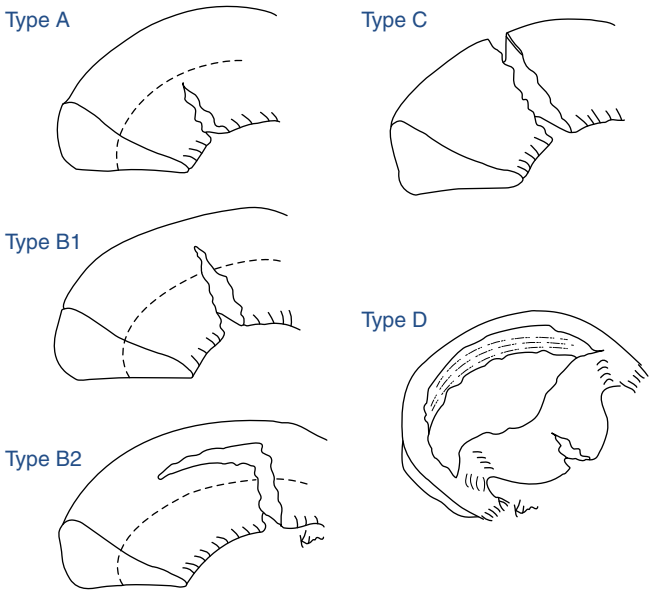

Fig. 1 Type of radial tear of meniscus. The tears were classified based on its length and shape of radial tear. Type A: The radial tear located in the inner zone within 50% of meniscal width. Type B: The radial split extended to more than 50% of width to the peripheral rim. According to the tear shape, Type B tears were further divided into the two subtypes: Type B1, simple radial split tear; Type B2, flap tear including radial tear. Type C: The complete radial split tear extended to the peripheral rim. Type D: The radial teal in bucket handle

Table 1 Location and type or radial tear that had been repaired

	Medial meniscus			Lateral meniscus		
	Ant.	Mid.	Post.	Ant.	Mid.	Post.
Type A ($n=2$)			1		1	
Type B1 ($n=6$)		1	2		2	1
Type B2 ($n=8$)		1	3		2	2
Type C ($n=9$)						9
Type D ($n=4$)		3				1
Total ($n=29$)	0	5	6	0	5	13

the inner zone within 50% of meniscal width, it was designated as Type A. When the radial split was extended to more than 50% of width to the peripheral rim, it was Type B. According to the tear shape, Type B tears were further divided into the following two subtypes: Type B1, simple radial split tear; Type B2, flap tear including radial tear. The complete radial split tear, which extended to the peripheral rim was classified Type C. The bucket handle tear including radial tear was designated as Type D. Location and type of radial tear that had been repaired were summarized in Table 1. The associated cartilage lesions were also evaluated using ICRS cartilage evaluation form.

Surgical Procedures and Postoperative Program

Under general anesthesia, patient was set using a leg holder and air-tourniquet. Conventional parapatellar anteromedial and anterolateral portals were used. Additional skin incision and exposure of posterior capsule was also performed according to the standard inside-out meniscus repair technique. At first, the surfaces of the meniscal tear and their surrounding area including synovium were rasped. Then repair was performed in an inside-out fashion with nonabsorbable 2-0 Ethibond sutures using Henning's instrumentation [32]. Autogenous fibrin clot was secured at the tear site unless combined ACL reconstruction surgery was performed [8]. The vertical sutures were first positioned near both edges of the tear site to put the disrupted circumferential fibers together and to reduce the displacement of torn meniscus (Fig. 2a). These sutures were also served as "a grip" for the following sutures. The horizontal mattress sutures were then placed perpendicular to and over the vertical sutures and the tear site (Fig. 2b). Finally, three or four horizontal sutures were placed at an interval of 2–3 mm and tied over the joint capsule to complete "Tie-Grip Suture" (Fig. 2c). Thus, the horizontal sutures reeled in the ends of tear site. After suturing meniscus, a probe was used to assess whether the gap was securely closed without suture slipping along the circumferential fibers.

Postoperatively, the knee was immobilized for 1–2 weeks depending on the severity of the meniscal tear, followed by gradual motion exercise with the limitation of knee flexion until 90° for the first 4 postoperative weeks. Partial weight bearing was allowed after 4 weeks, followed by full weight bearing at 6 weeks. Squatting beyond 90° and running activities were not allowed until 3 months. Sporting activities were permitted at 6 months.

Evaluations

Subjective symptoms and findings of the follow-up arthroscopy were reviewed. A comprehensive physical examination of the affected knee was performed with an emphasis on range of motion, joint crepitus, and femorotibial joint line tenderness. IKDC subjective score was also used.

At the follow-up arthroscopy, the repair site was probed to determine the stability of the remaining meniscus and quality of reparative tissue [8, 28]. Healing was considered "complete healing" when full-thickness apposition of the original tear occurred with no more than 10% of the original tear remaining. "Partial healing" was defined as follows: at least 50% of the original tear was healed, the repaired site

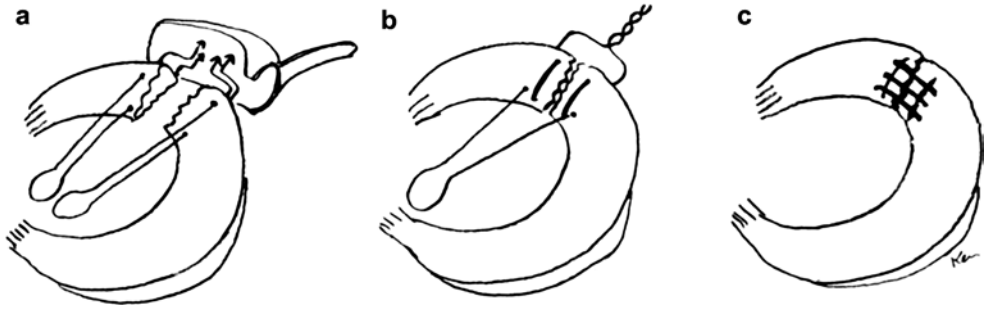

Fig. 2 The procedure of "Tie-Grip Suture." (**a**) The vertical sutures were first positioned near both edges of the tear site to reduce the displacement of torn meniscus. These sutures were also served as "a grip" for the following sutures. (**b**) The horizontal mattress sutures were then placed perpendicular to and over the vertical sutures and the tear site. (**c**) Finally, three or four horizontal sutures were placed at an interval of 2- to 3-mm and tied over the joint capsule to complete "Tie-Grip Suture." The horizontal sutures reeled in the ends of tear site

was stable by probing, and the meniscal body was in a normal position in the femorotibial joint. The repair was classified as "failure" if more than 50% of the original tear was present. The articular cartilage surfaces were also examined and graded according to ICRS cartilage injury evaluating package.

Patients

Between October 1999 and January 2003, 35 radial meniscus tears in 33 patients were repaired. There was no prior operation in any knees before meniscal repair. For inclusion in the study, the patient had to consent to have had a clinical examination at minimum 18 months follow-up, and second-look arthroscopic examination.

Twenty-seven patients (82%) met the criteria, while 6 of them were lost to follow-up. Two patients had two radial tears in the same knee, and both of them were repaired. Thus a total of 29 meniscal repairs in 27 patients were evaluated. There were 11 medial and 18 lateral menisci. Twenty-one patients (78%) also had a concomitant ACL tear in his or her knee joint, which was reconstructed with autogenous semitendinosus tendon graft at the same time. There were 12 women and 17 men whose mean age at the time of repair was 25.5 years with a range from 16 to 42 years. The average period from injury to meniscal repair was 8 months with a range, 2 days to 14 years. Twenty-five of the patients (93%) sustained the injury during sports activities.

The average period from surgery to follow-up physical examination was 18 months with a range from 12 to 26 months. All the patients were arthroscopically evaluated at a mean postoperative period of 9 months with a range from 2 to 22 months.

Results

Subjective and Physical Examination

At an average follow-up of 18 months, 24 out of 27 patients (89%) were free from meniscal symptoms including catching, locking, pain, or swelling, while the remaining 3 (11%) showed the following symptoms: two, effusion after strenuous activities, which could be managed conservatively. The other with catching required partial meniscectomy at the follow-up arthroscopy.

Arthroscopic Evaluation

Follow-up arthroscopy was performed for 29 repair sites in 27 patients at the time of removal of tibial fixation hardwares for ACL graft or for evaluation. Of the 29 menisci evaluated, 19 (66%) were classified as complete healing, 8 (28%) as partial healing, and 2 (7%) as failure according to the Horibe's evaluation criteria [20]. The overall rate of success in meniscal retention (complete healing or partial healing) was 93% (27 of 29). Two repaired menisci that were classified as failure required partial excision.

Even in complete split radial tear (Type C), eight out of nine repaired menisci showed complete healing (Fig. 3). There was no statistically significant difference on time interval from injury to repair for meniscal healing (Fig. 4).

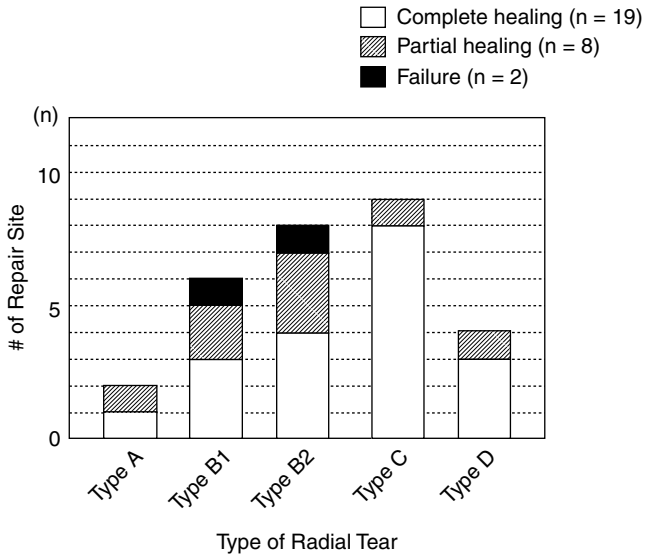

Fig. 3 The effects of type of radial tear on meniscal healing. There was no statistically significant difference on the type of radial tear for meniscal healing

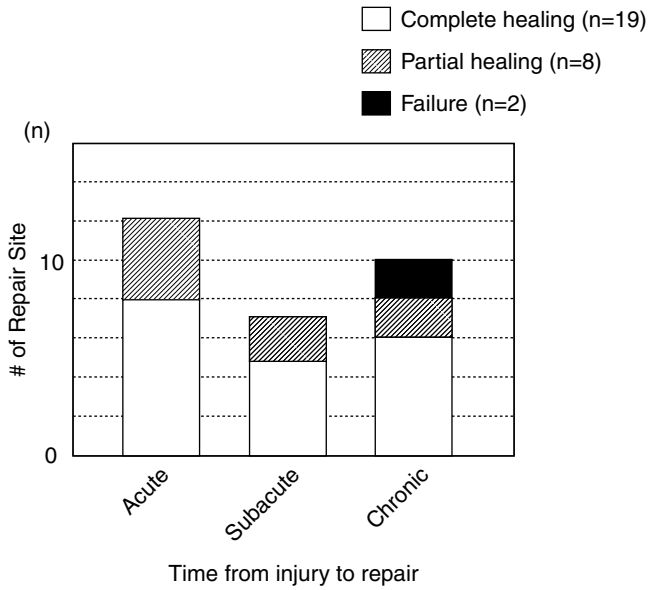

Fig. 4 The effects of time from injury to repair on meniscal healing. There was no statistically significant difference on time interval from injury to repair for meniscal healing

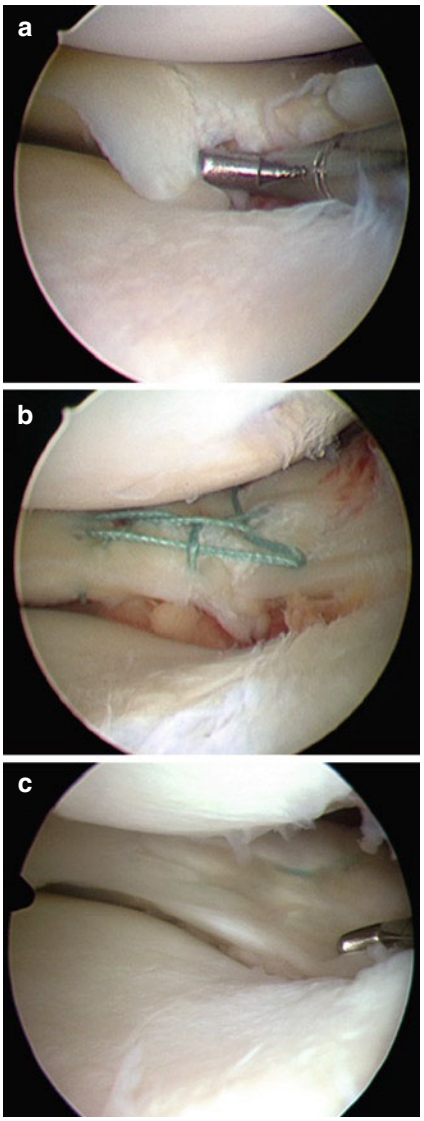

Fig. 5 Radial meniscal tear (Type B2) that had been repaired and had follow-up arthroscopy. (**a**) Posterior segment of the lateral meniscus in the right knee of 19-year-old female patients had radial tear of TypeB2, which extended to more than 50% of width to the peripheral rim with flap tear. (**b**) Radial tear was repaired with "Tie-Grip Suture" by eight sutures. (**c**) The follow-up arthroscopy performed at 6 months after the initial repair demonstrated that tear site was filled with reparative tissue with good continuity of circumferential structure. This was classified as "complete healing"

The repaired area of the meniscus within 6 months from the initial repair was filled with fibrous connective tissue by arthroscopy, whereas those tissues more than 1 year from the repair became harder by probing (Fig. 5). Synovial tissue with vasculature evidenced by arthroscopy without air tourniquet covered on the sutured area (Fig. 6).

Articular Cartilage

Abnormal cartilaginous surfaces beyond ICRS Grade 2 were found during the initial meniscal repair procedure in 7 (26%) of the 27 patients and all were associated with ACL tear. These cartilage lesions were seen in four on the lateral femoral condyle, two on the medial femoral condyle, and one on the lateral tibial plateau. There was no further deterioration of cartilage damage at the follow-up arthroscopy.

Complications

None of the patients experienced deep infection, neurovascular injury, limitation of knee motion, or other major complications.

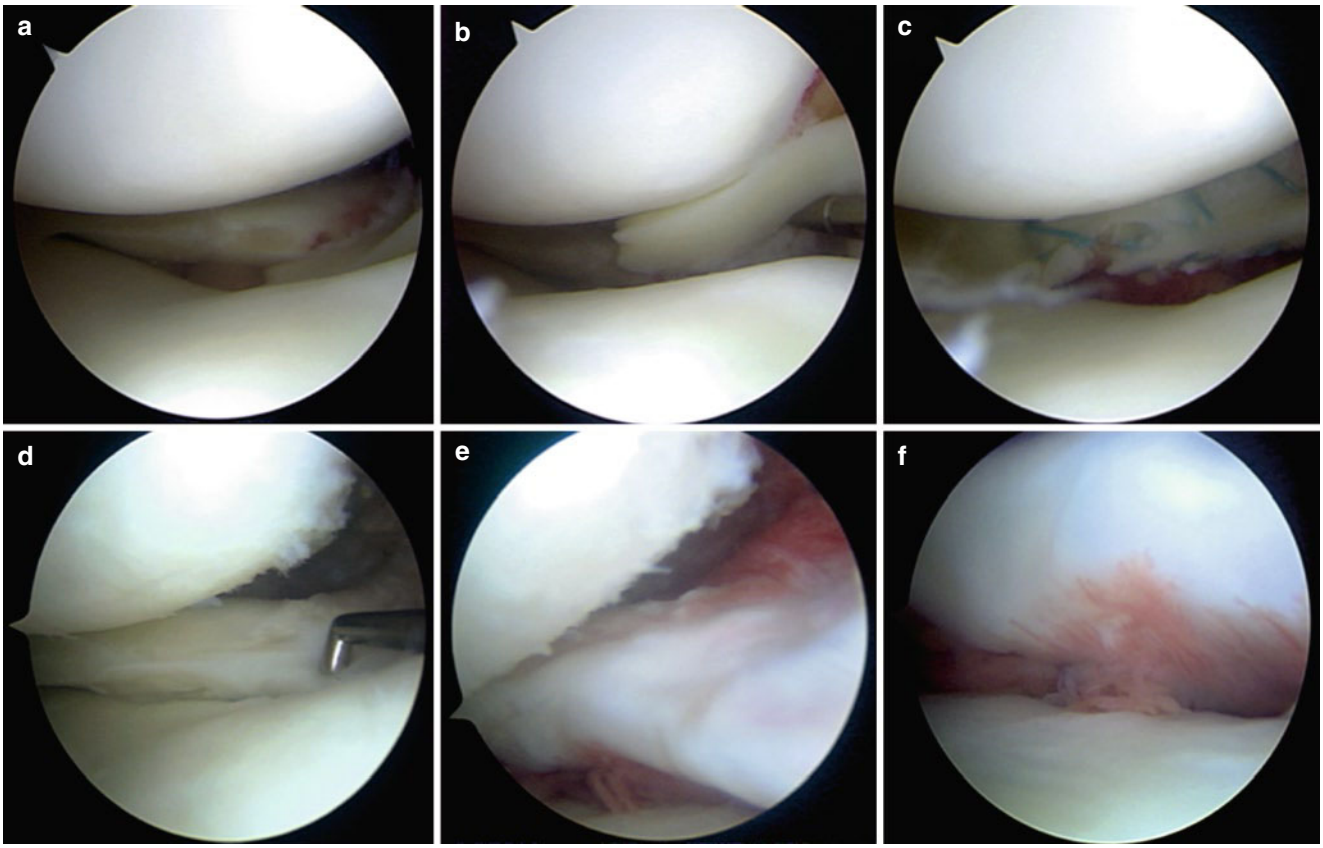

Fig. 6 Radial meniscal tear (Type C) that had been repaired and had follow-up arthroscopy. (**a**, **b**) Complete split radial tear at the posterior segment of the lateral meniscus in the right knee of 22-year-old female patients was evidenced by arthroscopy on 5 days after injury. (**c**) The vertical grip suture first positioned near both edges of the tear site to put the disrupted circumferential fibers together and to reduce the displacement of torn meniscus and then horizontal sutures were placed perpendicular to and over the vertical sutures to complete "Tie-Grip Suture." (**d**) The follow-up arthroscopy revealed that repaired site was filled with fibrous tissue at 4 months after operation. Probing the posterior segment of the meniscus caused the movement of the anterior segment of the meniscus, suggesting the continuity of circumferential structure. (**e**, **f**) The arthroscopic observation without air-tourniquet evidenced the vascularity of repaired tissue which comes from synovial fringe

Discussion

Radial tear that interrupts the circumferential fibers is problematic to repair because hoop strain causes separation of tear site. This type of tear including avascular zone of meniscus, furthermore, is poor in reparative process [6, 7, 21–23, 25]. Although short inner radial tears, which usually do not heal, may be asymptomatic shortly [35], 50% radial tear decreased the strains [21]. Complete split radial tear cannot be left alone because it becomes symptomatic and total meniscectomy is obliged to be performed [34]. The long-term consequences of a meniscectomy or even partial meniscectomy have been shown to be potentially deleterious to the joint surface [6, 13, 24, 30, 33].

There are only a few reports about the results of meniscal repair for radial tears. van Trammel and Rubman have reported four and five cases of meniscal repair of radial tears, respectively [31, 34]. van Trammel et al. performed meniscal repair for radial tear adjacent to the popliteus tendon using outside-in technique and a second-look arthroscopy 4 months after the initial treatment showed excellent healing in three of five patients [34]. Three patients that had been evaluated at average 71 months (range, 66–81 months) were clinically asymptomatic and MRI showed a fully healed meniscus at the repair sites. Rubman et al. also showed four cases of repair for radial tear with good results [31]. From these results, Rubman and Noyes recommended repair of meniscal tears that extend into the avascular central zone for young patients, especially those in the second and third decades of life, and highly competitive athletes who desire to participate in strenuous activities [31]. Encouraged by these results, we have developed a novel suture procedure in order to fix sutures more secure to hold hoop strain for active patients with radial meniscal tear. Indeed, 92% of our patients were injured their menisci during sport activities.

Our novel suture technique was developed to close the radial tear as firmly as possible. The vertical sutures at the both ends of the radial tear were first placed to reduce the displacement of the meniscus in the original position. At the same time, these vertical sutures are expected to serve as a grip to prevent slipping of the following horizontal sutures. By means of these vertical grip sutures, the horizontal sutures could reel in the ends of tear site firmly. Since radial tear disrupts the circumferential collagen fibers, the repair of

radial tear requires horizontal sutures to restore of the hoop structure of the meniscus. However, it is difficult to fix the radial tear firmly by suture because horizontal sutures which are placed parallel to the circumferential fibers causes cutting and/or slipping. The vertical grip sutures put the disrupted circumferential fibers together and prevented from cutting and slipping, thus, practically made it possible to repair the radial tear. After completion of "Tie-Grip Suture," we always confirm the continuity of circumferential structure. By pushing the anterior segment of the repaired meniscus body, the posterior segment of the meniscus moves anteriorly after successful "Tie-Grip Suture," which proves the transmission of hoop strain. Biomechanical strength and its characteristics of this suture remain to be examined.

There are many factors which affect the results of meniscal repair. Cruciate reconstruction surgery which creates bone tunnels to fix the tendon graft may have enhanced the healing potential for the meniscal repair because the mesenchymal cells migrate from the bone marrow and postoperative hemarthrosis provides serum protein, growth factors, and fibrinous framework to the tear [34].

Although the pattern of meniscal tears has been previously presumed to have an effect on healing, our results indicated that the type of tear may have had some effects on meniscal healing, but the differences were not statistically significant. It is noteworthy that even in complete radial split tear, type C, eight of nine showed complete healing and one displayed partial healing. It was evidenced by the second-look arthroscopy without air-tourniquet that avascular zone of meniscus in the repaired site was covered with hyper-vascular synovial tissue which come from synovial fringe (Fig. 6e, f). This may suggest that the surgical procedure of meniscal sutures in the avascular zone induces proliferation and migration of synovium beyond the normal limit of vascular access. Alternatively, the sutures may have produced vascular access channels which were thought to be advantageous for healing of meniscal repairs [3]. Furthermore, Tie-Grip Suture may have provided strong stability enough to allow reparative tissue to remain at the tear site and healing to occur. It needs further study whether human meniscus cells have a potential of proliferation to engage intrinsic healing in vivo, although we have shown the proliferation capacity of human meniscal cell in vitro [26].

There was no statistically significant difference on the meniscal healing for the factor of time interval from injury to meniscal repair. However, we believe that acute or subacute cases of meniscal tear would be more suitable to repair than chronic cases. In this study, two failures those were proven by the follow-up arthroscopy were chronic tears that had injured more than 1 year before the meniscal repair.

The limitation of this study was the evaluation method of the repaired meniscus functions. Newman et al. found in canine model that despite gross and histological healing in radial tears, the circumferential collagen fibers were not restored to their original biomechanical characteristics and, therefore, the ability to transmit load was not maintained [27]. The meniscal repairs in this study were evaluated with a physical and subjective examination, follow-up arthroscopic evaluation, knee flexion weight-bearing X-ray, and MR imaging. Although no clinically proved method or diagnostic test is currently available to determine the true function of a repaired meniscus, these evaluations can give an indication of meniscal function [31]. At an average of 18 months follow-up, 24 out of 27 patients (89%) were asymptomatic for tibiofemoral joint symptoms.

Conclusions

The follow-up arthroscopy, XP, MRI, and physical examination revealed that our novel arthroscopic meniscal repair technique for radial tear, "Tie-grip suture" was effective at an average of 18 months ranging from 12 to 26 months.

References

1. Annandale, T.: An operation for displaced semilunar cartilage. Br. Med. J. **1**, 779 (1885)
2. Arnoczky, S.P., Warren, R.F.: Microvasculature of the human meniscus. Am. J. Sports Med. **10**(2), 90–95 (1982)
3. Arnoczky, S.P., Warren, R.F.: The microvasculature of the meniscus and its response to injury. An experimental study in the dog. Am. J. Sports Med. **11**(3), 131–141 (1983)
4. Arnoczky, S.P., Warren, R.F., Spivak, J.M.: Meniscal repair using an exogenous fibrin clot. An experimental study in dogs. J. Bone Joint Surg. Am. **70**(8), 1209–1217 (1988)
5. Asahina, S., Muneta, T., Hoshino, A., Niga, S., Yamamoto, H.: Intermediate-term results of meniscal repair in anterior cruciate ligament-reconstructed knees. Am. J. Sports Med. **26**(5), 688–691 (1998)
6. Belzer, J.P., Cannon Jr., W.D.: Meniscus tears: treatment in the stable and unstable knee. J. Am. Acad. Orthop. Surg. **1**(1), 41–47 (1993)
7. Boyd, K.T., Myers, P.T.: Meniscus preservation; rationale, repair techniques and results. Knee **10**(1), 1–11 (2003)
8. Cannon, W.D., Vittori, J.M.: Meniscual repair. In: Aichroth, P.M., Cannon, W.D. (eds.) Knee Surgery – Current Practice. Martin Dunitz, London (1992)
9. Cooper, D.E., Arnoczky, S.P., Warren, R.F.: Arthroscopic meniscal repair. Clin. Sports Med. **9**(3), 589–607 (1990)
10. DeHaven, K.E.: Decision-making factors in the treatment of meniscus lesions. Clin. Orthop. Relat. Res. **252**(252), 49–54 (1990)
11. DeHaven, K.E.: Meniscus repair. Am. J. Sports Med. **27**(2), 242–250 (1999)
12. Eriksson, E.: Meniscus repair. Knee Surg. Sports Traumatol. Arthrosc. **11**(1), 1 (2003)
13. Fairbank, T.J.: Knee joint changes after meniscectomy. J. Bone Joint Surg. **30B**, 664–670 (1948)
14. Fithian, D.C., Kelly, M.A., Mow, V.C.: Material properties and structure-function relationships in the menisci. Clin. Orthop. **252**, 19–31 (1990)

15. Hantes, M.E., Zachos, V.C., Varitimidis, S.E., Dailiana, Z.H., Karachalios, T., Malizos, K.N.: Arthroscopic meniscal repair: a comparative study between three different surgical techniques. Knee Surg. Sports Traumatol. Arthrosc. **21**, 21 (2006)
16. Henning, C.E., Lynch, M.A.: Current concepts of meniscal function and pathology. Clin. Sports Med. **4**(2), 259–265 (1985)
17. Henning, C.E.: Current status of meniscus salvage. Clin. Sports Med. **9**(3), 567–576 (1990)
18. Henning, C.E., Lynch, M.A., Yearout, K.M., Vequist, S.W., Stallbaumer, R.J., Decker, K.A.: Arthroscopic meniscal repair using an exogenous fibrin clot. Clin. Orthop. **252**, 64–72 (1990)
19. Henning, C.E., Yearout, K.M., Vequist, S.W., Stallbaumer, R.J., Decker, K.A.: Use of the fascia sheath coverage and exogenous fibrin clot in the treatment of complex meniscal tears. Am. J. Sports Med. **19**(6), 626–631 (1991)
20. Horibe, S., Shino, K., Nakata, K., Maeda, A., Nakamura, N., Matsumoto, N.: Second-look arthroscopy after meniscal repair. Review of 132 menisci repaired by an arthroscopic inside-out technique. J. Bone Joint Surg. Br. **77**(2), 245–249 (1995)
21. Jones, R.S., Keene, G.C., Learmonth, D.J., et al.: Direct measurement of hoop strains in the intact and torn human medial meniscus. Clin. Biomech. (Bristol Avon.) **11**(5), 295–300 (1996)
22. Kim, Y.M., Rhee, K.J., Lee, J.K., Hwang, D.S., Yang, J.Y., Kim, S.J.: Arthroscopic pullout repair of a complete radial tear of the tibial attachment site of the medial meniscus posterior horn. Arthroscopy **22**(7), 795, e791–e794 (2006)
23. Kimura, M., Shirakura, K., Hasegawa, A., Kobuna, Y., Niijima, M.: Second look arthroscopy after meniscal repair. Factors affecting the healing rate. Clin. Orthop. Relat. Res. **314**, 185–191 (1995)
24. Lynch, M.A., Henning, C.E., Glick Jr., K.R.: Knee joint surface changes. Long-term follow-up meniscus tear treatment in stable anterior cruciate ligament reconstructions. Clin. Orthop. **172**, 148–153 (1983)
25. McCarty, E.C., Marx, R.G., DeHaven, K.E.: Meniscus repair: considerations in treatment and update of clinical results. Clin. Orthop. **402**, 122–134 (2002)
26. Nakata, K., Shino, K., Hamada, M., et al.: Human meniscus cell: characterization of the primary culture and use for tissue engineering. Clin. Orthop. **391 Suppl**, S208–S218 (2001)
27. Newman, A.P., Anderson, D.R., Daniels, A.U., Dales, M.C.: Mechanics of the healed meniscus in a canine model. Am. J. Sports Med. **17**(2), 164–175 (1989)
28. Noyes, F.R., Barber-Westin, S.D.: Arthroscopic repair of meniscus tears extending into the avascular zone with or without anterior cruciate ligament reconstruction in patients 40 years of age and older. Arthroscopy **16**(8), 822–829 (2000)
29. Ochi, M., Uchio, Y., Okuda, K., Shu, N., Yamaguchi, H., Sakai, Y.: Expression of cytokines after meniscal rasping to promote meniscal healing. Arthroscopy **17**(7), 724–731 (2001)
30. Rangger, C., Kathrein, A., Klestil, T., et al.: Partial meniscectomy and osteoarthritis. Implications for treatment of athletes. Sports Med. **23**(1), 61–68 (1997)
31. Rubman, M.H., Noyes, F.R., Barber-Westin, S.D.: Arthroscopic repair of meniscal tears that extend into the avascular zone. A review of 198 single and complex tears. Am. J. Sports Med. **26**(1), 87–95 (1998)
32. Scott, G.A., Jolly, B.L., Henning, C.E.: Combined posterior incision and arthroscopic intra-articular repair of the meniscus. An examination of factors affecting healing. J. Bone Joint Surg. Am. **68**(6), 847–861 (1986)
33. Sommerlath, K., Gillquist, J.: The long-term course of various meniscal treatments in anterior cruciate ligament deficient knees. Clin. Orthop. Relat. Res. **283**, 207–214 (1992)
34. van Trommel, M.F., Simonian, P.T., Potter, H.G., Wickiewicz, T.L.: Arthroscopic meniscal repair with fibrin clot of complete radial tears of the lateral meniscus in the avascular zone. Arthroscopy **14**(4), 360–365 (1998)
35. Weiss, C.B., Lundberg, M., Hamberg, P., DeHaven, K.E., Gillquist, J.: Non-operative treatment of meniscal tears. J. Bone Joint Surg. Am. **71**(6), 811–822 (1989)