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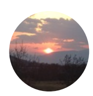

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Good Outcome After Meniscal Repair Using an All-Inside Suturing System in Combination With High-Frequency Biostimulation

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The reported hypercellular response in meniscal tissues seen within a few weeks after radiofrequency meniscectomy suggests that the meniscal tissue may repair itself when exposed to this technology.

The first attempts at meniscal repair are nearly as old as those for meniscectomy. However, technical difficulties, as well as the poor ability of meniscal tissue to heal, have limited the usage of repair techniques over time.

In recent years, the introduction of the all-inside meniscus repair technique has made the procedure easy, and as a consequence its use has increased. Several devices such as arrows, darts, screws, and fasteners have been progressively introduced; however, they are not biomechanically superior to mattress sutures.[1] The latest generation of all-inside devices combines the use of bioabsorbable materials and stitches in such a way that its final pullout strength is closer to the conventional suture. The FasT-Fix Meniscal Repair System (Smith & Nephew, Andover, Massachusetts) consists of two 5-mm polymer anchors with a braided #0 nonabsorbable suture with a pretensed knot.[2]

As the meniscus heals poorly, except on its most peripheral part, stimulation of revascularization at the lesion site is one of the most critical factors to obtain a good meniscal repair outcome in ruptures situated in the avascular area. For that reason, mechanical abrasion,[3,4] trephination,[5] or adding a fibrin clot[6,7] has shown a reasonable degree of success over the past decade.

High frequency or radiofrequency was first introduced for meniscal tissue ablation as an excision tool with good results. In this experimental work, using rabbits as a model, radiofrequency produced a line of necrosis of approximately 30 microns followed by a zone of hypercelullarity.[8] Those changes progressively disappeared, and the treated meniscus resembled a normal one on histological examination at the end of 6 months. Later, Miller et al[9] and Bert et al[10] confirmed this histological response in human menisci exposed to radiofrequency. This suggests that meniscal tissue histology returns to normality 6 months after being exposed to radiofrequency.[8-10]

The use of thermal energy promotes the activation of a cellular response and consequently meniscal healing. In 1998, Pavlovich[11] reported the first 4 cases of meniscal repair with the use of radiofrequency instead of meniscal rasping. Second-look arthroscopies showed all the menisci to be healed. In 2001, in an experimental work, Lopez et al[12] suggested that monopolar radiofrequency application on lacerated menisci may stabilize the tear by fusing collagenous tissue in the surrounding area and thereby prevent the propagation of the tear along tissue lines. More recently, Hatayama et al[13] confirmed the same effect; furthermore, they were able to demonstrate that radiofrequency caused fibroblast proliferation at 2 weeks after treatment and that the acellular or necrotic area was completely repopulated at 12 weeks. Therefore, it seems that exposing meniscal tissue to radiofrequency follows a predictable pattern of damage and recovery, characterized by the capacity for fibroblast proliferation during this recovery period and, finally, a return to the normal anatomy and histol-

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FINANCIAL DISCLOSURE

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ogy in a range of 6 to 12 weeks. The synovial tissue has been identified as the main actor in this particular repair process. It has a "tidal effect," first invading and eventually retiring from the spot to leave normal and healthy tissue behind.[14,15]

The present study evaluates the clinical and functional results of an arthroscopic suture done with the FasT-Fix system in combination with healing biostimulation of a chronic meniscal lesion with radiofrequency. Our hypothesis was that this combination would result in a healing rate similar to FasT-Fix in combination with already standard stimulation procedures.

Materials and Methods

A prospective study was carried out on a series 43 patients with a meniscus injury that was operated on over a 3-year period. The study group comprised 34 men (72.7%) and 9 women (27.3%) with an average age of 29.8 years.

The inclusion criterion was a total rupture of the meniscal tissue >10 mm in length (average, 25 mm; range, 10-45 mm) in either the red–white or white–white zone. All the tears were considered chronic, defined as >3 weeks old (range, 3 weeks to 2 years), as the patients came mainly from a waiting list of a public hospital. Those cases with chondral injuries requiring repair procedures that violate the subchondral bone were excluded. All the patients had had meniscal repair using the FasT-Fix suturing system with radiofrequency applied at the margins of the lesion.

The right knee was operated on in 24 cases (55.8%) and the left knee in 19 cases (44.2%). The medial meniscus was affected in 51.2% of the cases (22 knees) and the lateral meniscus in 48.8% of the cases (21 knees). Seven patients required a partial meniscectomy concomitantly to the suturing, be it the ipsilateral (42.8%) or contralateral (57.2%) meniscus. The type of rupture to repair was longitudinal in 81.4% of those located in the posterior horn. Eight cases (18.6%) showed a bucket handle tear. There was 1 case of a discoid meniscus with a radial rupture in the meniscal body associated with a bucket handle tear. In the aforementioned case, a combination of a partial meniscectomy and 1 horizontal stitch was used. The average number of sutures used for the repair was 2.3 (range, 1-5).

Fourteen patients (32.5%) had a tear of the anterior cruciate ligament (ACL) that was reconstructed with an autologous quadruple soft tissue graft at the same time as the meniscal repair. Knowing the possible effects of the blood-derived products provided by the bone tunnels on the meniscal healing, this particular group was studied and its results compared with the rest of the series.

Surgical Technique

Standard anterolateral and anteromedial arthroscopic portals were performed. After a complete arthroscopic assessment of the meniscal tear, the tear margins and adjacent synovial tissue were debrided and stimulated with the Serfas Energy Radiofrequency Ablation System (Stryker, Mahwah, New Jersey) to induce a healing response. According to Pavlovich,[15] several centripetal movements from the adjacent synovial tissue to the tear site, including both lips of the tear, were performed. The mode of the Serfas was set on coagulation and the output potency was 4/10. Then the meniscal suture was done following the recommended standard technique for the FasT-Fix system.[2] The suturing device was inserted in such a way that a maximum perpendicular approach to the tear was obtained. Either an ipsilateral or contralateral standard portal was used to the aforementioned end. A vertical suture was placed every 5 to 10 mm to obtain good fixation. In some instances, a horizontal suture was placed behind the meniscus to increase the stability of the construct. Neither mechanical abrasion, nor trephination, nor any procedure aimed to increase the vascular supply of the ruptured meniscus was performed.

Rehabilitation

All patients followed the same strict rehabilitation protocol. The protocol was designed to promptly reestablish full extension and quadriceps activation. It permitted proprioceptive weight bearing and continuous passive movement from 0° to 90° over the first 3 weeks and progressed to full weight bearing and full flexion at approximately 6 weeks. Running was permitted from 12 weeks. A return to full activity was allowed at approximately 4 months.

Evaluation

All patients were evaluated using the Lysholm functional scale and the subjective scale of the International Knee Documentation Committee (IKDC). A postoperative improvement of the Lysholm score of >10 points was considered clinically relevant.

The meniscal repair was considered a failure when there was joint line pain during light or normal activities of daily living, a positive McMurray sign, or persistent knee locking or swelling requiring subsequent surgical procedures on the repaired meniscus.[16]

All patients were preoperatively evaluated with Rosenberg view radiographs and magnetic resonance imaging (MRI). Radiographic assessment was scheduled at 12-month follow-up. Postoperative MRI was done on 26 patients (63.4%).

Statistical Analysis

To analyze the extent of improvement of the Lysholm score as well as the IKDC, the obtained data were tested using the Student *t* test for paired data. The level of significance was set at $P<.05$.

Results

Forty-one patients (32 men and 9 women) with an average age of 29.8 years were postoperatively evaluated at an average of 26.1 months (range, 18-47 months). Two patients were lost to final follow-up.

The subjective IKDC score was excellent (90-100) in 23 patients (56.1%), good (89-90) in 14 patients (34.1%), and fair (70-79) or bad (<70) in 4 pa-

Table

Patient Parameters

	No. Patients (%)
Pain	
Never	23 (56.1)
Light with exercise	16 (39)
Marked with exercise	2 (4.9)
Constant	0 (0)
Limp	
Never	34 (82.9)
Light or periodic	7 (17.1)
Support	
None	41 (100)
Locking	
Occasional	1 (2.4)
Instability	
Never	31 (75.6)
Rarely with exercise	5 (12.2)
Frequent with exercise	0 (0)
Occasional daily activity	2 (4.8)
Frequent daily activity	3 (7.4)
Edema	
No	33 (80.5)
With exercise	5 (12.2)
With day-to-day activity	3 (7.3)
Climbing stairs	
Without limitation	34 (83)
Light	6 (14.6)
One step at time	1 (2.4)
Squatting	
Without problem	22 (53.7)
Light limitation	16 (39)
No >90°	3 (7.3)

tients each (9.8%). The number of patients with positive findings in each of the parameters is shown in the Table. Overall, a postoperative knee function average of 86.37 was achieved on the IKDC subjective scale.

Statistically, both the subjective IKDC and the Lysholm scores improved. The IKDC scores averaged 59 preoperatively and 92 postoperatively ($P<.009$). The Lysholm scores averaged 60.9 preoperatively and 91.96 postoperatively ($P<.008$). According to the clinical evaluation, the success rate was 90% in the whole series.

No changes were seen in the Rosenberg view at final follow-up according to Ahlback's criteria when compared to the preoperative radiological examination. With respect to the MRIs, the repaired site can always be recognized by an altered signal. It was a constant finding in this series, particularly in the posterior horn of the medial meniscus (Figures 1, 2). One may wonder if it corresponds to what Scott et al[17] refers to as a partial healing or a lack of sensitivity of the MRI when dealing with immature scar tissue.

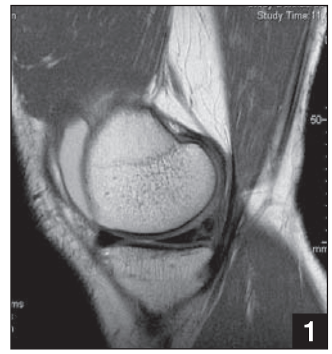
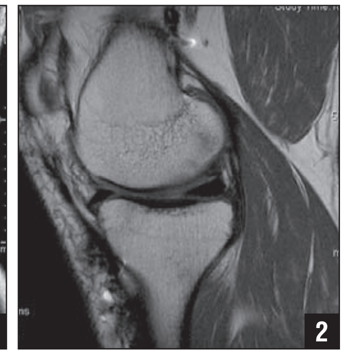

Figure 1: An oblique rupture site clearly seen in the posterior horn of a medial meniscus on sagittal MRI. **Figure 2:** A healing of the previous meniscal rupture can be seen on 1-year postoperative MRI.

Six patients (18%) underwent second-look arthroscopies for different reasons. Three of them showed no meniscal pathology and the sutured rupture had healed. They consisted of 1 extension loss after combined ACL reconstruction, 1 unconfirmed suspicion of postoperative septic arthritis, and 1 case of knee stiffness in a medial meniscus bucket handle tear that needed 5 stitches to be properly fixed. All 3 cases were operated on within 6 months after index surgery. A failure of the suture and a rerupturing was encountered in the rest. In 2 of them, a partial meniscectomy had to be performed, while resuturing was possible in 1 case and the patient did well afterwards.

Four patient results (9.7%) were considered to be failures at the time of the final evaluation, the 2 previously meniscectomized and 2 more with a symptomatic knee. All of them had joint line pain and/or effusion on carrying out activities of daily living or moderate physical activity. Only 1 patient had a positive McMurray sign, and none had knee locks.

In an effort to identify factors that might influence the results, we specifically compared the failures obtained in the ACL reconstruction subgroup of 14 patients (1 failure, 92.9% success rate) with the rest of the series (29 patients) where meniscal repair was done alone (3 failures, 89.7% success rate). However, no statistical differences were found ($P<.832$).

As far as intra- and postoperative complications, 2 cases of subcutaneous granuloma were registered in the place corresponding to a stitch, 1 of which required its withdrawal through a mini-incision. One case of a failed intraoperative suture required redoing. There were no neurovascular complications.

Discussion

The healing process of the meniscal tissue in the avascular area has not been fully understood. It seems to consist of the proliferation of fibrous connective tissue that eventually modulates into fibrocartilaginous tissue at the tear site.[18] The repairing fibroblastic cells seem to originate both from the superficial layer of the injured meniscus[19] as well as from the adjacent synovium.[20] This particular tissue contains cells that may have the ability to convert from synoviocytes to fibrocytes, and so its contribution to the healing process may be crucial.[3,20] Finally, the scar tissue undergoes a maturation process over a long period of time, probably modulated by the compression forces the meniscus withstands.

It is widely accepted that meniscal injuries older than 3 weeks and/or situated in an avascular area (>3 mm from the meniscus–synovial junction) do not heal spontaneously.[3-6,20] Over the past 20 years, several additional techniques have been introduced to promote meniscal healing in these circumstances. Thus, when dealing with either a chronic or an avascular meniscal injury, current knowledge accepts that promoting meniscal healing is as important as achieving mechanical stability of the tear.[3-7]

The all-inside technique has become popular since its introduction, and its use has extended due to the advantages of the procedure and its ease of use. However, clinical outcomes of the different meniscal repair devices vary considerably, ranging from 57% to 100%.[21] Recently, third-generation all-inside devices for meniscal repair have overcome the problems and complications of the first generation. Their biomechanical properties compare favorably to the gold standard mattress sutures and show greater strength over earlier generations of meniscal repair devices.[22,23] Some studies have recently demonstrated excellent results with of FasT-Fix, one of the third-generation meniscal repair devices, when combined with appropriate stimulation of the rupture site. The success rate was approximately 90%.[23-26] Although the conventional mattress suture has remained the gold standard in biomechanical terms, various studies have demonstrated that FasT-Fix shows rigidity, strength, and resistance to cyclical or constant loading similar to resistant sutures and is superior to other fixation methods.[27-29]

The present study shows that good clinical results can also be achieved with chronic avascular meniscal tears with the combination of the FasT-Fix system and radiofrequency used as a healing biostimulation tool at mid-term follow-up.

Scott et al[17] were the first to propose meniscal abrasion as a crucial measure to induce healing in areas were the vascular supply is not guaranteed. Other procedures like trephination or the introduction of a fibrin clot have been shown to improve the healing rates in avascular injuries and hence increase the indications for repair.[3] However, some authors have suggested that the distance from the meniscus periphery to the defect is too great for abrasion therapy to sufficiently stimulate cellular ingrowths enough to facilitate repair of tears in the avascular region.[20] On the other hand, trephination has been criticized for destroying the meniscal collagen net ultrastructure and thus the functional ability of the meniscus to withstand compressive forces.[7]

A high-frequency or radiofrequency current is an alternating electrical current that has a frequency of ⩾10,000 cycles per second. Although radiofrequency had been used in surgical procedures for years, Schosheim and Caspari[8] first described the in vivo effects of electrosurgical radiofrequency meniscectomy. At 2 weeks, microscopic examination showed a necrotic zone of 0.05 to 0.15 mm followed by a hypercelullar zone and normal tissue. All these changes evolved over a 3-month period and finally returned to normal by 6 months.[8] Some years later, Miller et al[9] reported on the acute histological effects of radiofrequency meniscectomy in human beings. They found an average thermal damage depth of 0.29 mm. Two patients had a biopsy at 7 and 21 months after index surgery, and the menisci at the surgical sites were found to be histologically indistinguishable from normal tissue.[9] More recently, Bert[10] reported on a large series of >900 radiofrequency meniscectomies. The histological results of his investigation again supported Schosheim and Caspari's[8] findings in the sense that the menisci are able to sustain acute thermal damage and normalize their histology in approximately 6 months.[10]

The effects of radiofrequency on some other soft tissues have also been evaluated. Lopez et al[30] demonstrated that joint capsular tissues showed collagen fusion and pyknosis of ficrochondrocyte nuclei when exposed to radiofrequency. In a subsequent study, the same group speculated that these same effects can be extrapolated to cover meniscal healing in an ovine model. They found that monopolar radiofrequency was able to stabilize a meniscal tear by fusing collagenous tissue in the surrounding area and thus prevent the propagation of the tear along tissue lines.[12]

Iñigo-Pavlovich's[31] study on 32 Barbados sheep demonstrated that the exposure of meniscal tissue to radiofrequency at 40 watts created a transition zone between the necrotic and the living tissue. After 12 weeks, meniscus histology had returned to normality as seen in hematoxylin-eosin stains. The surgically created tears in meniscal avascular areas completely healed. Therefore, and in accordance with previous observations, the meniscal tissue submitted to radiofrequency was found to have gone through a process of necrosis and subsequent recovery. The involvement of synovial tissue in this process was clearly noted.[31] More recently, Hatayama et al[13] investigated the histological changes that radiofrequency prompted when applied to a meniscal repair in a rabbit model. They found that fibroblasts extended from the parameniscal synovium on the femoral surface and invaded the acellular area of the meniscus. These findings again suggest that the synovium might contribute to repopulation of the radiofrequency-treated meniscal tears. Therefore, the effects of radiofrequency on meniscal tears may not only be the fusion of collagen fibers but the stimulation of a synovium healing response via activation of fibroblast proliferation and migration.

One concern when using radiofrequency is its possible collateral effects on the hyaline cartilage. Some studies suggest that cartilage can be damaged by radiofrequency thermal energy and that this injury worsens over time.[32,33] Whereas osteonecrosis has been reported as a direct consequence of the use of radiofrequency,[34] it has been shown that this complication may occur spontaneously in a symptomatic medial meniscus degenerative tear without arthroscopic surgery.[35] Recently, it has been suggested that some of the previously reported problems, such as chondrocyte death, associated with radiofrequency might be related to the high joint fluid temperatures reached during arthroscopy. However, this collateral effect can be overcome by maintaining an adequate fluid flow rate to lower joint fluid temperatures.[36]

Analysis of the current results through the clinical evaluation of the patient may not appear to be as reliable as evaluation with MRI or arthroscopic examination. However, studies demonstrate that a good clinical evaluation is a trustworthy way of evaluating the status of a meniscus repair,[16,36] and even that MRI examinations are not superior to accurate clinical examinations.[27]

The main limitation of this study was the lack of a comparative series in which other current treatments were used. However, we feel that our previous experience using FasT-Fix in combination with mechanical abrasion (unpublished data) as well as the substantial current literature on the same issue is a good standard for comparison. Furthermore, the fact that the subgroup of ACL simultaneous reconstruction has the same failure rate as the isolated meniscal repair group suggests that radiofrequency itself is the main factor in promoting meniscal healing.

Conclusion

The reported hypercellular response in meniscal tissues seen within a few weeks after radiofrequency meniscectomy[8-13] suggests that the meniscal tissue may repair itself when exposed to this technology. The present study shows that the combination of an all-inside suture with radiofrequency stimulation can obtain the same success rate in terms of healing as the combination with other current methods. Therefore, we believe that radiofrequency is a promising application as a promoter of the meniscus healing response that warrants further investigation.

References

1. Diduch DR, Poelstra KA. The evolution of all-inside meniscal repair. *Operative Techniques in Sports Medicine*. 2003; 11(2):83-90.
2. Caborn D. *Meniscal repair with the FasT-Fix suture system*. Andover, MA: Smith & Nephew, Inc, Endoscopy Division; 2002. http://global.smith-nephew.com/cps/rde/xbcr/smithnephewls/1061031B.pdf
3. McAndrews PT, Arnoczky SP. Meniscal repair enhancement techniques. *Clin Sports Med*. 1996; 15(3):499-510.
4. Uchio Y, Ochi M, Adachi N, Kawasaki K, Iwasa J. Results of rasping of meniscal tears with and without anterior cruciate ligament injury as evaluated by second-look arthroscopy. *Arthroscopy*. 2003; 19(5):463-469.
5. Zhang Z, Arnold JA, Williams T, McCann B. Repairs by trephination and suturing of longitudinal injuries in the avascular area of the meniscus in goats. *Am J Sports Med*. 1995; 23(1):35-41.
6. Sethi PM, Cooper A, Jokl P. Technical tips in orthopaedics: meniscal repair with use of an in situ fibrin clot. *Arthroscopy*. 2003; 19(5):E44.
7. Arnoczky SP, Warren RF, Spivak JM. Meniscal repair using an exogenous fibrin clot. An experimental study in dogs. *J Bone Joint Surg Am*. 1988; 70(8):1209-1217.
8. Schosheim PM, Caspari RB. Evaluation of electrosurgical meniscectomy in rabbits. *Arthroscopy*. 1986; 2(2):71-76.
9. Miller MD, Kline AJ, Gonzales J, Beach WR. Pitfalls associated with FasT-Fix meniscal repair. *Arthroscopy*. 2002; 18(8):939-943.
10. Bert JM. Use of an electrocautery loop probe for arthroscopic meniscectomy: a five-year experience with results, indications, and complications. *Arthroscopy*. 1992; 8(2):148-156.
11. Pavlovich RI. Hi-frequency electrical cautery stimulation in the treatment of displaced meniscal tears. *Arthroscopy*. 1998; 14(6):566-571.
12. Lopez MJ, DeTemple LA, Lu Y, Markel MD. The effects of monopolar radiofrequency energy on intact and lacerated ovine menisci. *Arthroscopy*. 2001; 17(6):613-619.
13. Hatayama K, Higuchi H, Kimura M, et al. Histologic changes after meniscal repair using radiofrequency energy in rabbits. *Arthroscopy*. 2007; 23(3):299-304.
14. Pavlovich RI. Radiofrequency: future applications for current knowledge. *Int Orthop*. 2005; 29(1):65-66.
15. Pavlovich RI. Radiofrequency and meniscus: from excision to repair. *Sports Med Arthrosc Rev*. 2005; 13(4):193-197.
16. Barrett GR, Field MH, Treacy SH, Ruff CG. Clinical results of meniscus repair in patients 40 years and older. *Arthroscopy*. 1998; 14(8):824-829.
17. Scott GA, Jolly BL, Henning CE. Combined posterior incision and arthroscopic intra-articular repair of the meniscus. An examination of factors affecting healing. *J Bone Joint Surg Am*. 1986; 68(6):847-861.
18. McDevitt C, Mukherjee S, Kambic H, Parker R. Emerging concepts of the cell biology of the meniscus. *Current Opinion Orthop*. 2002; (13):345-350.
19. Ghadially FN, Wedge JH, Lalonde JM. Experimental methods of repairing injured menisci. *J Bone Joint Surg Br*. 1986; 68(1):106-110.
20. Nakhostine M, Gershuni DH, Anderson R, Danzig LA, Weiner GM. Effects of abrasion therapy on tears in the avascular region of sheep menisci. *Arthroscopy*. 1990; 6(4):280-287.
21. Lozano J, Ma CB, Cannon WD. All-inside meniscus repair: a systematic review. *Clin Orthop Relat Res*. 2007; (455):134-141.
22. Rankin CC, Lintner DM, Noble PC. Paravic V, Greer E. A biomechanical analysis of meniscal repair techniques. *Am J Sports Med*. 2002; 30(4):492-497.
23. Barber FA, Herbert MA, Richards DP. Load to failure testing of new meniscal repair devices. *Arthroscopy*. 2004; 20(1):45-50.

24. Kotsovolos ES, Hantes ME, Mastrokalos DS, Lorbach O, Paessler HH. Results of all-inside meniscal repair with the FasT-Fix meniscal repair system. *Arthroscopy*. 2006; 22(1):3-9.
25. Haas AL, Schepsis AA, Hornstein J, Edgar CM. Meniscal repair using the FasT-Fix all-inside meniscal repair device. *Arthroscopy*. 2005; 21(2):167-175.
26. Pujol N, Panarella L, Selmi TA, Neyret P, Fithian D, Beaufils P. Meniscal healing after meniscal repair: a CT arthrography assessment. *Am J Sports Med*. 2008; 36(8):1489-1495.
27. Borden P, Nyland J, Caborn DN, Pienkowski D. Biomechanical comparison of the FasT-Fix meniscal repair suture system with vertical mattress sutures and meniscus arrows. *Am J Sports Med*. 2003; 31(3):374-378.
28. Zantop T, Eggers AK, Weimann A, Hassenpflug J, Petersen W. Initial fixation strength of flexible all-inside meniscus suture anchors in comparison to conventional suture technique and rigid anchors: biomechanical evaluation of new meniscus refixation systems. *Am J Sports Med*. 2004; 32(4):863-869.
29. Kocabey Y, Chang HC, Brand JC Jr, Nawab A, Nyland J, Caborn DN. A biomechanical comparison of the FasT-Fix meniscal repair suture system and the RapidLoc device in cadaver meniscus. *Arthroscopy*. 2006; 22(4):406-413.
30. Lopez MJ, Hayashi K, Fanton GS, Thabit G III, Markel MD. The effect of radiofrequency energy on the ultrastructure of joint capsular collagen. *Arthroscopy*. 1998; 14(5):495-501.
31. Iñigo-Pavlovich RF. Cambios morfológicos in vivo del tejido meniscal tras la exposición a impulsos de radiofrecuencia en modelo animal de cordero barbados. [Tesis doctoral]. Madrid, Spain: Universidad Complutense de Madrid; 2005.
32. Edwards RB III, Hayashi K, Lu Y, Markel MD. The acute effects of radiofrequency energy in articular cartilage: an in vitro study. *Arthroscopy*. 2001; 17(1):112-113.
33. Caffey S, McPherson E, Moore B, Hedman T, Vangsness CT Jr. Effects of radiofrequency energy on human articular cartilage: an analysis of 5 systems. *Am J Sports Med*. 2005; 33(7):1035-1039.
34. Encalada I, Richmond JC. Osteonecrosis after arthroscopic meniscectomy using radiofrequency. *Arthroscopy*. 2004; 20(6):632-636.
35. Muscolo DL, Costa-Paz M, Ayerza M, Makino A. Medial meniscal tears and spontaneous osteonecrosis of the knee. *Arthroscopy*. 2006; 22(4):457-460.
36. Morgan CD, Wojtys EM, Casscells CD, Casscells SW. Arthroscopic meniscal repair evaluated by second-look arthroscopy. *Am J Sports Med*. 1991; 19(6):632-637.

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