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Current Status of The Application of Different Sutures For Meniscus

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Abstract. The meniscus plays a critical role in preserving the knee's normal physiological function, which includes proprioception, stabilising the joint, nourishing and lubricating it, increasing the contact area of the articular surfaces and the match between the tibia and femur, and bearing distributed stress and shock. When people are exposed to external forces that cause their knees to twist, meniscus injury may result. However, if the meniscus is removed for resection, the likelihood of developing osteoarthritis in the knee joint increases. As arthroscopy technology has advanced, the goal of treating meniscus injuries is to keep as much of the damaged meniscus intact as feasible while also attempting to repair the meniscus by suturing as much of it as possible, if it is possible. In order to provide some reference for the clinical research of arthroscopic suture meniscus, this article presents the structure of the meniscus, focuses on various suture techniques for the treatment of arthroscopic meniscus injuries, and evaluates their benefits and drawbacks, as well as the proper suture techniques for various injuries.

Keywords: Meniscus injury; Inside-out suture; All-inside suture; Knee function; Curative effect.

1. Introduction

Treatment options for meniscal injuries, a somewhat prevalent knee condition among clinical sports injuries, include conservative measures and surgery. This diaease has an annual new incidence rate of 0.06–0.07%. Open total meniscectomy and subtotal meniscectomy of the knee joint are the conventional meniscus therapies for this condition. However, additional research has revealed that, based on tests and analysis of the meniscus's fundamental structure and function, a diseased meniscus will increase the load on the knee joint. As a result, a traditional meniscectomy will hasten the damage to the knee joint cartilage, which will eventually result in secondary osteoarthritis of the knee joint. In order to maintain the overall structure of the meniscus, it is now generally agreed that sutures or particular medical devices should be used to treat meniscal lesions. In order to maintain the knee joint's biomechanics and avoid premature degenerative changes of the knee joint due to secondary knee osteoarthritis, minimally invasive knee arthroscopy techniques have replaced meniscal suturing as the treatment for meniscal injuries due to the rapid advancement of technology. The benefits of minimally invasive arthroscopic meniscal repair are decreased trauma, bleeding, and recovery time. Meniscus suturing is not appropriate for all meniscus injuries, though, and various suturing methods have varied degrees of effectiveness and a particular range of applications. To increase the precision of surgical selection and the standard of patients' postoperative recovery, it is crucial to research the range of applications and relative effectiveness of various meniscal suture procedures. This article aims to examine the current state of arthroscopic application of three different types of meniscal sutures—All-inside suture, Inside-out suture and Outside-in suture—as well as the clinical effectiveness and suitability of different suture techniques for various tear types.

2. Structure and Function of the Meniscus

The main constituents of the meniscus, a fibrocartilaginous structure with a wedge-shaped cross-section, are water, collagen, and glycosaminoglycans. Depending on where it is located, the meniscus can be classified as medial or lateral, and it occupies roughly 1/2 to 2/3 of the tibial plateau. The C-shaped medial meniscus is about 4 cm in length, with an average width of about 10 mm and an

average thickness of about 4 mm. The lateral meniscus, in contrast, is O-shaped, measuring around 12 mm in width and 5 mm in thickness and width.

Because of its relationship to the anterior and posterior meniscofemoral ligaments, the lateral meniscus can move up to 9-11 mm, but the medial meniscus can only move 2-5 mm. The posterior portion of the medial meniscus is attached to the anterior aspect of the ACL, and its edges are fused to the knee capsule. The posterior capsule is located directly beneath the superior surface of the medial meniscus, forming a hidden area of meniscal Ramp injury. The posterior portion of the medial meniscus is wider than the anterior one, and its anterior portion is firmly attached to the tibia anterior to the ACL. The lateral meniscus's small size and great mobility, as well as the overlap of its anterior portion with the ACL's attachment site at the tibia, may cause anterolateral root damage during ACL reconstruction surgery if surgical access is not chosen carefully. Conversely, the posterior horn of the lateral meniscus is situated between the posterior cruciate ligament and the intercondylar eminence. Research indicates that injuries to the medial meniscus occur more frequently than those to the lateral meniscus.

Cells in all parts of the meniscus have a similar ability to regenerate, although their repair potential is mostly determined by blood supply. The meniscus's blood supply is mostly provided by the branches of the superior and inferior geniculate arteries that surround its edges, forming a dense capillary network that penetrates 10-30% of the medial meniscus and 10-25% of the lateral meniscus. The meniscus is separated into three primary regions based on its blood supply: the red-red region, the red-white transition zone, and the white-white region. The red-red zone, or the part of the meniscus within 3 mm of the edge, has the best blood supply and thus a relatively high healing capability. The red-white zone is described as the range of 3 to 5 mm, which has a blood supply and the ability to heal between the red-red and white-white regions. Areas greater than 5 mm are classed as white-white areas, which have the least blood supply and thus the lowest healing capacity. In actual practice, meniscal lesions in the red-red and red-white transition regions can frequently be treated with suture surgery because the blood supply in these locations is adequate to promote wound healing. Suture surgery, on the other hand, is frequently ineffectual for injuries in the white-white zone; hence, these injuries have historically been deemed unsuitable for repair. Recent investigations, however, have revealed the existence of pluripotent mesenchymal stromal cells in the white-white region, as well as microvascular neovascularisation, implying that even meniscal injuries in the white-white region may be healable.

3. Clinical Surgical Repair Modalities for Meniscal Injuries

In the past, meniscal injuries were treated with total or subtotal meniscectomy, but these two surgical methods can lead to secondary cartilage damage and degeneration and are less commonly used nowadays. With the development of arthroscopic technology, arthroscopic meniscus injury repair surgery is now commonly used in clinical practice, and there are three main ways: Inside-out suture, Outside-in suture, and All-inside suture.

3.1. Inside-out Suture

The inside-out suture is the earliest of the meniscal suture techniques to be developed. It is mainly indicated for rupture of the middle 1/3 and posterior horn of the meniscus. An incision must be made from the posterior medial or posterior lateral assisted incision, and by using an arthroscope inside the knee, the suture needle is threaded through the joint cavity and then knotted and secured from the outside of the joint. Studies have shown that this technique is prone to injury to the saphenous and common peroneal nerves and can also cause complications such as meniscal cyst formation, synovitis, and popliteal artery pseudoaneurysms. A randomised controlled trial (n = 631), comparing the inside-out suture method with the all-inside suture method, showed that there was no significant difference in the rate of good healing between patients in the all-inside suture group and those in the inside-out suture group. Meanwhile, the results of the final follow-up suggested that there was no difference in

the complication rate and joint function score between the two groups. The only difference between the two groups was that the average operation time was shorter for patients in the total internal suture group.The clinical data of 62 patients with posterior horn tears of the medial meniscus were retrospectively analysed, and they were divided into the all-inner suture group (35 patients) and the inner and outer suture group (27 patients) according to the suture repair scheme [1]. The results showed that the intraoperative operation time of the total internal suture group was shorter than that of the internal and external suture group, and the clinical healing rate and MRI healing rate were higher than that of the internal and external suture group. After treatment, the VAS scores of the two groups were lower than those before our treatment, and the IKDC scores were higher than those before our treatment, and the VAS scores of the all-inner suture group were lower than those of the inner and outer suture groups. In another randomised controlled trial, internal and external sutures and all internal sutures were performed in 36 patients with simple tears of the posterior meniscus body. The results showed that the healing rate was 94.44% in the internal and external groups and 88.89% in the total internal group. It can be seen that the internal and external suture method has higher flexibility in dealing with patients with torn meniscus and can be useful in dealing with all kinds of torn meniscus injuries. The effectiveness of its suture has also been proven to be reliable in several studies, but it is necessary to prevent neurovascular injuries caused by making a posterior incision. The use of the inside-out suture is recommended for more complex meniscal tears with narrow joint spaces or for patients who are sensitive to the cost of surgery.

3.2. Outside-in Suture

It is relatively less traumatic to the joint as it does not require complex operations inside the joint. The procedure is much simpler and requires relatively less skill and experience on the part of the surgeon. The external internal suture method is mainly suitable for anterior horn and middle 1/3 of meniscus injuries, but also for radial meniscus tears or tears at the edge of the meniscus and may be less suitable for deep or complex tears. However, the method is punctured from the outside, requiring an auxiliary incision, and the position and angle of the suture may be limited and less flexible than the internal and external suture method. In addition, there is a risk of injury to blood vessels and nerves around the joint when puncturing from the outside. Wang Gongze selected patients with meniscus body injuries to undergo total internal suture method (n = 45) and external internal suture method (n = 45). The results found that postoperative Lysholm score, IKDC score and HSS score in both groups were higher than those before surgery, and the outer-inner suture group was higher than that of the all-inner suture group, with a statistically significant difference ($P<0.05$); the occurrence of postoperative complications in the two groups was similar, and the difference was not statistically significant ($P>0.05$) [2]. Zhou Chaodong conducted 3-month and 6-month postoperative follow-up of 44 patients with total internal suture and external internal suture surgery for knee meniscus body injuries and found that the differences in Lysholm score and VAS score were statistically significant ($P<0.05$), but there was no significant difference in knee joint mobility ($P>0.05$); moreover, there was no significant difference in postoperative signs between the two groups ($P>0.05$) [3]. Li Peng selected patients with meniscus injuries to undergo the external internal suture method and the total internal suture method, respectively, in 48 cases each. The operation time and intraoperative bleeding in the observation group were significantly lower than those in the control group ($P\leq0.05$); there was no statistically significant difference in the length of hospital stay, postoperative signs, and Lysholm, Tegner, and IKDC scores between the two groups ($P\leq0.05$) [4]. Huang Xingguo et al. performed external internal suture and total internal suture on 176 patients with meniscus injuries [5]. The results showed that the operation time, intraoperative bleeding, and hospital stay of the total internal group were significantly lower than those of the external internal group ($P < 0.05$), and the intersegmental pressure pain, joint strangulation, and Mcmurray's sign were significantly better than those of the control group ($P < 0.05$). It can be seen that the internal-external suture method is minimally invasive and easy to access the anterior middle third of the meniscus, and since it does not require complex operations inside the joint, it is relatively less traumatic to the joint, with good repair results and a high rate of clinical excellence, and it can be selected according to the type of injury with different

suture methods. Compared with the Inside-out suture methods, the Outside-in suture method is simpler in operation and requires less skill and experience from the surgeon. Therefore, the Outside-in suture is particularly suited to meniscal rim tears and may be less suitable for deep or complex tears.

3.3. All-Inside Suture

The All-inside suture method uses special arthroscopic instruments, usually consisting of a penetrating needle with preloaded sutures and an anchor pin to hold the sutures in place. The method performs all operations inside the joint without the need for puncture or knotting outside the joint and is therefore less invasive and quicker to recover. It is mainly indicated for posterior horn ruptures of the meniscus, especially medially. This technique does not require an auxiliary incision, is less likely to damage blood vessels and nerves, and has a shorter operation time. However, the disadvantages of this technique are that it is prone to graft rupture and cartilage damage, and the cost of surgery is expensive. Feng Yinzhen selected 32 patients who were diagnosed with meniscal tears at the popliteal tendon and underwent arthroscopic all-inside suture, and all of them were followed up for 6 months after the operation, and the results showed that the Lysholm score, Tegner score, and KSS score were significantly higher, and the VAS score was lower and the joint mobility was higher [6]. Li Jin treated 76 patients with meniscal tears with total internal suture repair, and the clinical healing rate was 85.53%. After 12-month follow-up, complete healing by MRI was 64 cases (84.21%) and partial healing was 8 cases (10.53%). Lysholm score was significantly higher ($P<0.05$) [7]. Chen Tonglei performed arthroscopic meniscal revision + meniscal suture in 23 patients with horizontal meniscal tears. The VAS score decreased; the Lysholm score, IDKC score, and Tegner's knee motion score increased significantly [8]. Chen Lu et al. performed arthroscopic total medial meniscal suture in 43 meniscal tears. With an average follow-up of 18.5 months, the clinical healing rate was 86.05% as evaluated by Barrett's criteria; the Lysholm score, IKDC score, and KSS score were significantly higher, and the differences were statistically significant ($P<0.05$) [9]. It can be seen that all operations of the total internal suture method are completed within the joint, which reduces extra-articular trauma and facilitates the patient's postoperative recovery. The operator can operate under direct arthroscopic vision, which simplifies the surgical steps and shortens the operation time. As puncture outside the joint is not required, the risk of injury to blood vessels and nerves is reduced. Its advantage lies in its minimally invasive nature and ease of operation, which makes it particularly suitable for the repair of marginal meniscal tears. Meanwhile, it is safe and effective, with good efficacy, and is a clinically reliable method of meniscal suturing.

4. Different Types of Meniscus Tears and Applicable Therapies

4.1. Longitudinal Tear of the Meniscus

This is the most common type of injury. Because the medial meniscus is relatively fixed, has less range of motion, and is more susceptible to shear forces, this type of tear usually occurs in the central region of the meniscus, especially in the posterior third of the medial meniscus. Medial menisci occur three times more often than lateral menisci. Longitudinal tears may be limited to a small portion of the meniscus or may extend across the entire width of the meniscus. It is usually due to trauma acting on a relatively normal meniscus. An internal tear line extends along the longitudinal direction of the meniscus, starting at the edge of the meniscus and going deeper inward. In contrast to other types of tears, longitudinal tears may affect the edge structure of the meniscus, so it is usually associated with meniscal stability. Meniscal barrel-handle tears are a special form of longitudinal tears, sometimes originating from vertical (longitudinal) and horizontal tears, and are most often seen in younger patients with severe trauma.

Ogawa, H. et al. treated 25 patients with longitudinal tears by applying sutures, compared the clinical therapies and healing of the patients, and showed that the application of internal and external sutures resulted in good clinical outcomes [10]. Li Xiang et al. showed that the internal and external meniscal

suture method was suitable for patients with arthroscopic anterior cruciate ligament reconstruction of meniscal barrel shank-like tears [11]. Niu Xingyue et al. found that the internal and external suture method was more suitable for meniscal body tears, while the total internal suture method required more experience and skill from the operator [12]. The operator needs to judge the timing of the strike of the bandage tab with experience, and the thicker suture needle used in this suture method may lead to further damage to normal meniscal tissue, especially when dealing with chronic injuries or tears with poor tissue quality; the all-inside suture method is more difficult to operate. Yan Hankun et al. showed that the use of internal and external sutures could be more effective in reducing surgical bleeding and improving postoperative pain in patients with lateral disc meniscus injuries of the knee. Xu Lihu performed arthroscopic anterior cruciate ligament reconstruction and closure of medial meniscus barrel shank tear in 65 patients (37 patients in the all-inside suture group and 28 patients in the inside-out suture group). The all-inside suture was shorter than the inside-out suture, and there was no difference in the incidence of postoperative joint function and positive symptoms, whereas there was a risk of saphenous nerve infrapatellar injury in the inside-out suture. In conclusion, meniscal barrel shank-like tears can be treated with all-inside and inside-out sutures. It is recommended that inside-out sutures be used to close the meniscal body, while all-inside sutures can be used to close the meniscal body posteriorly, so that the meniscal body, which is under the greatest suture tension, can be reliably secured to the joint capsule and the risk of intraoperative vascular and nerve injuries can be reduced.

4.2. Horizontal Tears of the Meniscus (Laminar or Fish-mouth Tears)

Horizontal tears of the meniscus often stratify the meniscus, most often presenting a horizontal tear from the free edge of the meniscus towards the synovial rim, forming an upper and lower layer. Such tears are most commonly seen in the posterior half of the medial meniscus or the middle of the lateral meniscus. Horizontal tears occur as a result of shear forces, may be caused by acute trauma or chronic wear and tear, and are commonly seen in the elderly, athletes, and those engaged in repetitive knee activities. Horizontal tears are characterised by a tear line parallel to the edge of the meniscus, which differs from the vertical orientation of longitudinal tears and the radial orientation of radial tears. Many flap tears and compound tears begin as horizontal tears.

Li Chengye et al. performed arthroscopic outside-in meniscal suture repair in 31 patients with anterior horn level tears of the meniscus and followed up for a period of 12.4 (12.2±3.7) months [13]. The results showed an improvement in Lsyholm knee score. No complications were observed in all patients, and the symptoms of activity limitation improved to different degrees compared with the preoperative period. Arthroscopic outside-in suture technique was performed to repair the anterior horn of the meniscus injury, and the postoperative knee symptoms improved significantly. Chen Tonglei et al. performed arthroscopic meniscal repair + meniscal suture on 23 patients with horizontal meniscal tears, and the follow-up time was 12 months. The results showed that the VAS pain score was reduced, the Lysholm score, the International Knee Documentation Committee (IKDC) score, and the Tegner Knee Motion Score were increased after the operation ($P<0.01$), and the clinical success rate was 87%. The clinical success rate was 87%. In conclusion, the arthroscopic Outside-in suture method can be used to treat horizontal meniscal tears with simple operation, quick operation time, and good postoperative recovery, which is worthy of clinical promotion.

4.3. Radial Tear of the Meniscus (Radial Tear)

Radial tears, which can form a bird's beak pattern, are vertically orientated grade III high signals within the meniscus, most commonly in the middle 1/3 (body) of the lateral meniscus and in the junction area of the body and anterior horn, and can result in complete loss of meniscal function. Radial tears are characterised by a tear line that radiates from the central region of the meniscus towards the margins, resembling the shape of the sun's rays. This tear usually occurs in the medial portion of the meniscus and often breaks the ring of fibres that run along the periphery, which may cause the central region of the meniscus to separate from the margins. When this radial or oblique

tear extends to the synovial membrane, there is a complete loss of extension of the meniscus, which greatly affects the normal conduction of loads.

Fifteen patients with radial tears of the posterior horn of the lateral meniscus (PHLM) received treatment with the FasT-Fix Meniscus treatment System during anterior cruciate ligament restoration [14]. The postoperative evaluation employed the Lysholm Knee Score in conjunction with the Tegner Activity Level. The mean follow-up length was 24 months. The findings revealed an impressive clinical success rate of 100%. Both the Lysholm Knee Score and Tegner Activity Level demonstrated considerable improvement when compared to their preoperative values. Additionally, during the follow-up arthroscopy, radial tears of the PHLM were addressed alongside ACL reconstruction using the FasT-Fix device in 86.6% of the instances, resulting in complete or partial healing. In addition,Feltz et al. discovered that using region-specific trocars with varying degrees of curvature for both internal and external suturing provided significant flexibility in addressing radial tears in different areas of the lateral meniscus through the rebar technique. The needles, with their distinct curvatures, were adept at managing radial tears extending from the middle to the posterior horn of the lateral meniscus. This approach also reduces trauma to the meniscus since the needle used for inside-out repairs is smaller than that for all-inside sutures. Nonetheless, tackling tears in the anterior horn of the lateral meniscus remains challenging with this method. Radial tears in the anterior horn of the lateral meniscus can be managed using an external internal suture. One of the most technically challenging aspects of this technique relates to the tie of the all-inside meniscus repair suture. In summary, radial tears of the PHLM meniscus can be repaired using both all-inside and inside-out sutures; outside-in sutures are preferred for repairs of tears in the anterior horn of the lateral meniscus.

4.4. Ramp Damage

Ramp injuries are tears in the posterior horn of the meniscus near the synovial rim, particularly in the area of the posterior horn of the medial meniscus, which is known as the "ramp" area. This injury usually involves the joint between the meniscus and the joint capsule and is associated with an ACL injury that may lead to instability or detachment of the posterior horn of the meniscus. Ramp injuries may cause pain and dysfunction in the back of the knee, especially when squatting or kneeling. Diagnosing a ramp injury may require special imaging techniques, such as specific sequences on an MRI. Tears in other areas of the meniscus vary in location and treatment and usually involve surgical repair to re-establish the structure and stability of the posterior horn of the meniscus.

Thaunat et al. exhibited favourable outcomes with All-inside suture repair of ramp injuries utilising a suture hook via the posterior medial portal [15]. Chen Z. et al. performed anterior cruciate ligament replacement with meniscal repair utilising the FasT-Fix approach on the knees of 46 patients diagnosed with concomitant anterior cruciate ligament injuries and ramp lesions [16]. After an average follow-up period of 32 months, the Lysholm Knee Score and the International Knee Documentation Committee (IKDC) objective score were considerably elevated. The clinical healing rate was 97.8%. The FasT-Fix meniscal ramus repair technique showed excellent healing results when utilized alongside ACL reconstruction. A second arthroscopic procedure was performed on 39 patients with ramp injuries and showed 82.1% complete healing, 15.4% incomplete healing, and 2.6% failure. The cases with complete healing were all at the site where the posterior horn was sutured with a total internal suture, while incomplete healing occurred at the site of the medial-lateral suture. In conclusion, the all-inside suture method of repairing the posterior horn of the medial meniscus by assisting the posterior medial portal can be considered integrally for the repair of ramp injuries.

4.5. Diagonal Tear

An oblique tear of the meniscus is an oblique fracture of the meniscus along its long axis. This tear usually occurs on the medial or lateral side of the meniscus and develops as a result of the complex stresses placed on the knee during twisting or compression. The patient's pain may increase during specific movements such as squatting, jumping, or twisting. Sometimes, the torn meniscus edges may become lodged in the joint space, leading to joint interlocking. On MRI images, oblique tears usually

appear as linear areas of high signal within the meniscus, positioned at an oblique angle to the longitudinal axis of the meniscus. If surgical treatment is performed, meniscal repair is applied in younger patients or when the tear is located in the red-red zone of the meniscus. If the tear cannot be repaired, a partial meniscectomy or a complete meniscectomy may be required.

Tsujii, A. et al. Internal and external suturing of posterolateral meniscal oblique tears with the zigzag suture technique resulted in complete or partial healing in only 61% of patients [17]. Furumatsu, T. et al. treated 20 posterior meniscal radial or oblique tears using a 360-degree All-inside meniscal suture with a significant improvement in the final Lysholm score, Tegner score, and IKDC scores [18]. Thus, in patients with asymptomatic oblique meniscal tears suffering from mild osteoarthritis of the knee, All-inside suture can be effective in preventing deterioration of MME. In conclusion, All-inside suture can be used for the management of oblique meniscal tears.

5. Conclusion

The meniscus is an important component in maintaining the structure and function of the knee, and early diagnosis and treatment are crucial for meniscal recovery. Meniscectomy accelerates the progression of osteoarthritis in the knee; therefore, meniscal repair treatment is a hot topic nowadays, which can maximise the preservation of meniscus function and structure, and at the same time, a more suitable repair device should be selected according to the different tear patterns. Each of the above 3 types of meniscal injury sutures have its own advantages and disadvantages, and different parts of the meniscus are suitable for different types of sutures. However, they are mainly suitable for repairing injuries in the red-red and red-white zones and are less effective in repairing injuries in the white-white zone, as well as in repairing horizontal tears and other complex tears. At the same time, the operator's habit and operation proficiency also have a great influence on the choice of suture method. It is believed that with the development and innovation of medical technology, the arthroscopic repair of meniscus injuries will have a broader future.

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