Technical Note

Application of Continuous Sewing Machine-Like Suture Technique in Meniscus Injury

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Abstract: Meniscus injury is a common type of knee joint injury and often requires arthroscopic repair. At present, meniscus repair methods mainly include inside-out technology, outside-in technology, and all-inside technology. Among them, all-inside technology has attracted more attention from clinicians because of its better results. To improve the shortcomings of all-inside technology, we describe a "continuous sewing machine-like" suture technique. Our technique can make the meniscus suture continuous, increase its flexibility, and also enhance the stability of the suture knot through multiple puncture suture. Our technology can be applied to more-complex meniscus injuries and can greatly reduce the cost of surgery.

Knee meniscus injury is very common. The main types of meniscus injury include posterior horn tear, body tear, anterior horn tear, bucket-handle tear, and root injury.[1-5] Severe meniscus injury can lead to instability of the knee and, without standard surgical treatment, easily can lead to more complex bone and joint diseases, such as osteoarthritis.[6] Therefore, it is necessary to pay more attention to the surgical treatment of meniscus injury. Meniscus suture methods vary, and clinicians often use different suture methods for different kinds of tears. For the tear of the posterior horn of the meniscus, the all-inside suture method is often used.[1] For the tear of the anterior horn, the outside-in technique is often selected. The root tear of the meniscus is a common injury. To reattach the meniscus to the bone surface, the "transtibial pull-out" technology often is used.[7]

Fig 1. A suture hook with traction suture loaded. The yellow arrow indicates the suture hook, whereas the black arrow indicates that a sufficient length of traction suture should be left at the distal end of the suture hook. In addition, in the relevant description, the A end of the suture represents the free end located at the front of the suture hook, and the B end represents the other free end, as indicated in the figure.

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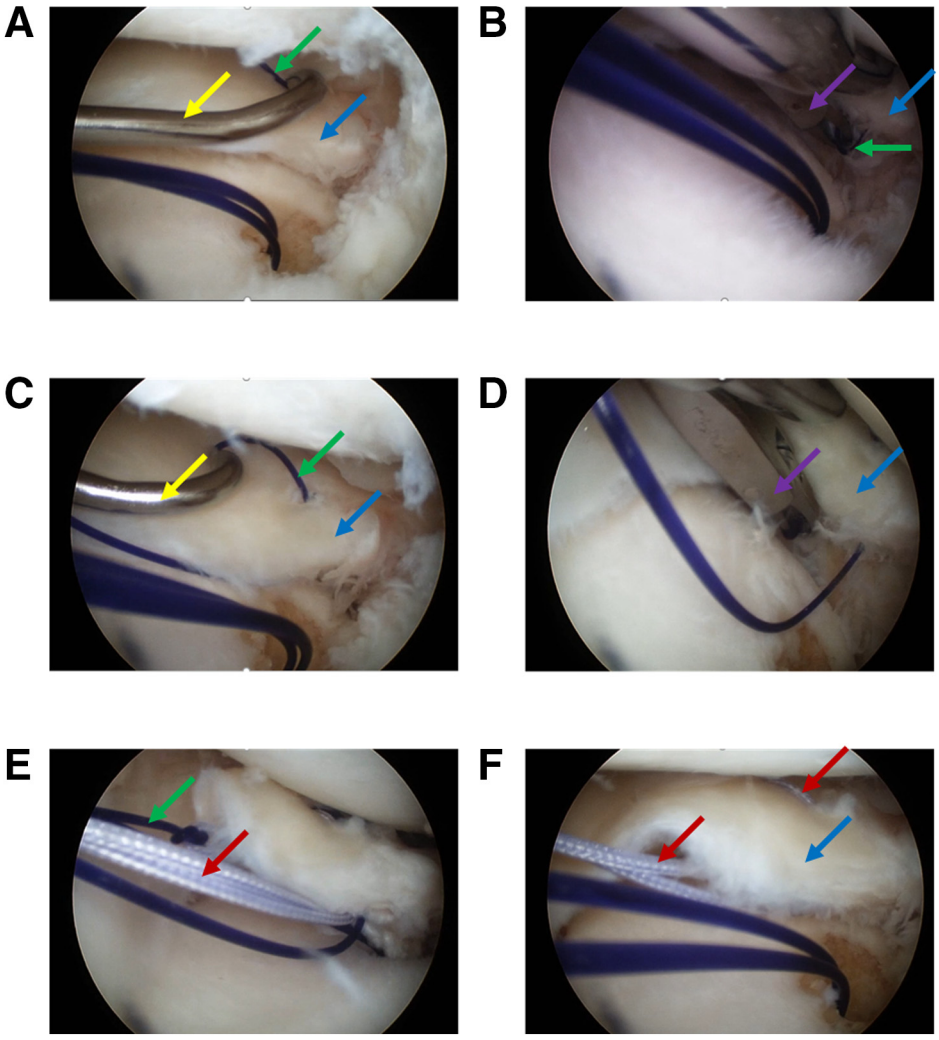

Fig 2. The specific process of puncture and suture using a suture hook with traction suture. In this demonstration, the anterolateral approach is the observational approach, the anteromedial approach is used for suture hook operations, and the medial auxiliary approach is used for clamp operations. (A) The first puncture. The yellow arrow indicates the suture hook, the green arrow indicates the traction suture, and the blue arrow indicates meniscus (same as below in the figure). As shown, there is the sufficient length traction suture left at the front of the hook, and this is the state for piercing. (B) Clamp the suture ring. The purple arrow indicates the clamp (same as below in this figure). We can choose the right approach to clamp the suture loop. (C) Withdraw the suture hook for the second puncture. The key point is to exit the hook without exiting the traction suture. We can use clamp to secure the suture. As shown, the second puncture is similar to the first. (D) The second puncture. Similarly, we use a clamp to grab the traction suture. The puncture is usually performed only twice during the suture process using traction lines. Thus, the suture ring can be pulled out directly in the second puncture. (E-F) The process of pulling high-strength suture with traction suture. The red arrow points to high-strength suture. After tying the end of a traction suture to the end of a high-strength suture, the high-strength suture can be pulled out by traction suture.

Different suture methods have their own advantages and disadvantages. For example, although the outside-in technique can be directly completed by lumbar puncture needle, the whole process is time-consuming, and it is inappropriate for the tear of the posterior horn of the meniscus. The inside-out technique can control the insertion site of the meniscus in the joint, but it requires specialized surgical instruments and carries an increased risk of neurovascular injury.[8] The inside-out technique is not suitable for suturing the anterior horn.

All-inside technology is now more popular among clinicians because they can use suture device technology, suture hook technology, and other methods.[9,10] All-inside suture device technology is widely used, simple, fast, and can be applied to almost all types of meniscus injury. However, its application is limited because of its high costs.[11] As for all-inside suture hook technology, its application is limited because of its need of multiple operations, indispensable traction process, and the high technical requirements for the clinician.

Fig 3. An example of patient posture and the position of the arthroscopic approaches. Patients usually can be placed in a hemilithotomy position. The observation approach and the operation approach can be selected based on the specific disease location. A medial auxiliary approach is marked with orange arrow for suture hook operation. In our example, the anterolateral approach is used as the observation approach, as shown by the black arrow in the figure. The anteromedial approach is an operational approach for clamp operation, as indicated by the brown arrow.

Therefore, it is necessary to improve all-inside technology. We describe an improved version of all-inside technology, namely a continuous sewing machine-like suture technique, to better complete the treatment of meniscus injury. With our technology, clinicians can be more flexible in the choice of needle placement during surgery and can save on consumables, which makes the surgery more economical.

Surgical Technique (With Video Illustration)

Traditional all-inside technology follows the principle of "one needle, one hole, with one traction suture at a time." This means that in traditional techniques, in order for a high-strength meniscus suture to pass through the meniscus each time, a suture hook with traction suture should be used independently to pass through the meniscus. If the high-strength meniscus sutures need to pass through the meniscus several times, the aforementioned steps need to be repeated, which is not only time-consuming but also complicated, resulting in waste of consumable materials. With our suture technology, these problems can be avoided and "continuously needle puncturing, a total of one high-strength suture, with or without traction suture" can be achieved.

Herein, we describe the process of our meniscus continuous suturing method with our modified technology using traction suture. First, we thread the traction suture (PDS II; Ethicon, Somerville, NJ) into the suture hook (IDEAL Suture Shuttle, 45 DEGREES RIGHT; DePuy Mitek, Raynham, MA). Unlike traditional techniques, the distal end of the suture hook requires a certain length of traction suture reserved (i.e., the A end), as shown in Figure 1. The specific suture process is shown in Figure 2. The first puncture is performed (Fig 2A). After the puncture to the exit side of the suture is made, clamp the suture ring (Fig 2B), pull out the A end of the suture, and slowly withdraw the suture hook for the second puncture (Fig 2C). The second puncture is performed in a similar manner to the first (Fig 2D). After 2 punctures of a traction line, the suture hook is removed, the traction suture is knotted with the high-strength suture (ORTHOCORD SUTURE; #2 VIOLET W/ MO-7 1/2 CIRCLE, TAPER POINT NEEDLE, 22 mm; DePuy Mitek), and the high-strength suture is pulled into place (Fig 2 E-F). It should be noted that only 2 punctures were performed using the suture hook with traction suture in the aforementioned example. However, our technology can directly omit the use of the traction suture and use a suture hook loaded with a high-strength suture directly, as shown in Appendix Figure 1, available at www.arthroscopyjournal.org. More punctures are possible and convenient when meniscus sutures are performed using a suture hook loaded with high-strength sutures, which is shown in Video 1. Only one high-strength suture is used in the whole process when the hook loaded with high-strength thread is used for multiple sutures. In particular, for multiple sutures, the A end of suture should be passed through the loop formed in second puncture, as well as the third or more continuous puncture, and the B end should be pulled out after the last continuous puncture. Finally, we knot and fix the ends A and B of the suture to gather all pierced parts together with one suture, which increases the stability of the knot and makes it less prone to tearing the meniscus.

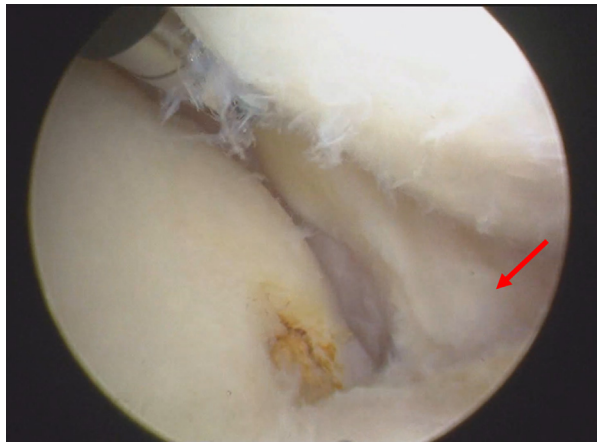

Fig 4. Arthroscopic appearance of meniscus root tear. The red arrow indicates the area of the rupture. The separation of the meniscus root from the tibia is shown in the figure.

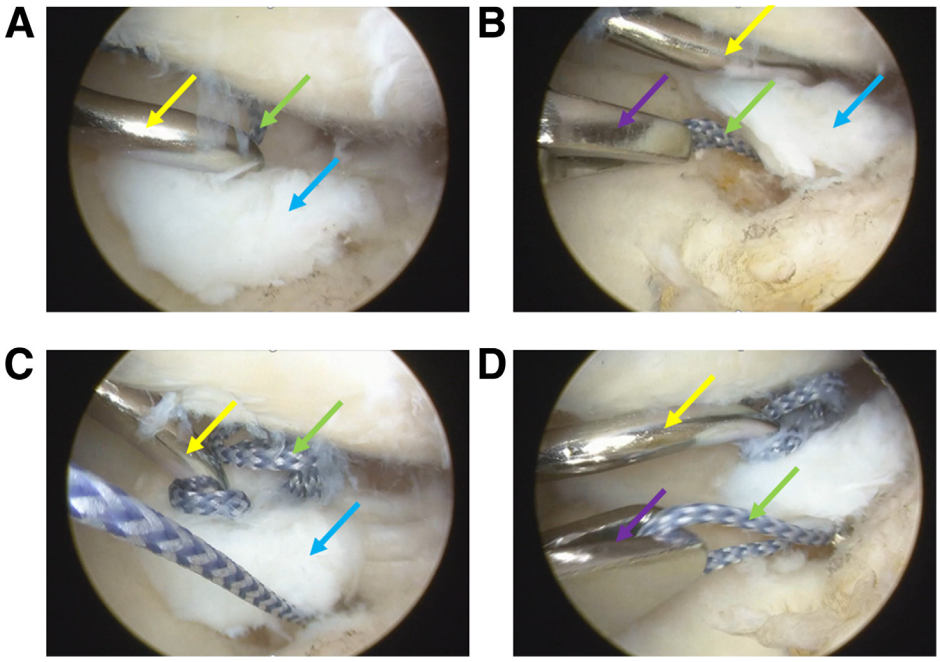

Fig 5. Continuous twice sutures process using a hook that directly loads the high-strength suture. In this demonstration, the anterolateral approach is the observational approach, the medial auxiliary approach is used for suture hook operations, and the anteromedial approach is used for clamp operations. (A) The first puncture. The yellow arrow indicates the suture hook, the green arrow indicates high-strength suture, and the blue arrow indicates meniscus (same below in the figure). As with the loading of traction suture, it is equally necessary to leave a sufficient length of high-strength suture at the front of the hook. (B) Clamp the suture ring. The purple arrow indicates the clamp (same below in the figure). Similarly, we can insert clamp into the side of the suture ring pierced out and hold the suture ring. (C-D) Withdraw the suture hook and finish the second puncture. The second puncture is similar to the first.

Clinical Application Demonstration

We present a meniscus root tear repair and meniscus centralization to introduce our modified technique. We perform the operation using a suture hook loaded with high-strength suture. The operation is carried out with the patient under general anesthesia. Patients are placed in a supine position with knee flexed. A baseline physical examination, including knee range of motion and the McMurray sign, is performed. The physical examination is repeated twice, and imaging data are used to preliminarily determine the site of injury. The affected lower limb is then disinfected and a standard anterolateral approach is made as a "visual approach" for arthroscopic evaluation of the injured site, as shown in Figure 3. However, it is important to point out that as for these 3 approaches, clinicians can set their functions as needed, for example, the anteromedial approach also can be used as a "visual approach." In this case, arthroscopy revealed a tear in the root of the meniscus (Fig 4). We then use the anteromedial approach as the operational approach using the suture hook. Also, in general, we may need to create a medial auxiliary approach for the operation of clamp, as shown in Appendix Figure 2, available at www.arthroscopyjournal.org.

Next, we perform 2 cases of puncture operations as the examples to illustrate our modified technique. The first example of suturing is shown in Figure 5. In this case, the suturing process involves 2 punctures. It is also feasible for multiple groups of puncture operations to complete the repair of meniscus root tears, as shown in Figure 6. We can see that with our modified technology, the position and frequency of needle penetration can be flexibly selected. Therefore, we can form knots of different shapes. In the second case, the 3 puncture positions on the meniscus could form a triangle, which enhances stability. When the meniscus root is sutured, the surgeon can pull the thread out of the tibia tunnel and fix it. The same suture method is used for centralization of the meniscus. The continuous sewing machine-like suture technique of the meniscus body can be applied. In conclusion, our modified continuous sewing machine-like suture technique can be used in most parts of the meniscus, and the overall process is similar, which brings great convenience to the surgeon.

Postoperative Protocol

For patients undergoing surgery using our modified continuous sewing machine-like suture technique, the

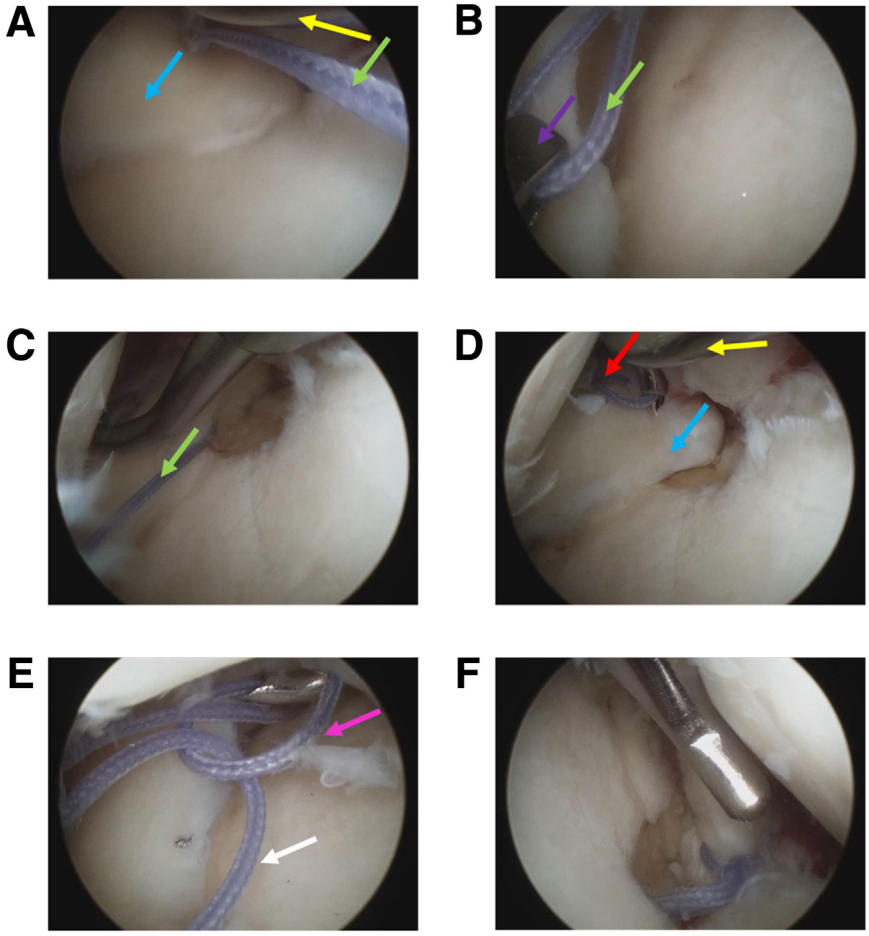

Fig 6. Continuous triple sutures process to complete the repair of meniscus root tears. In this demonstration, the anteromedial approach is the observational approach, the anterolateral approach is used for suture hook operations, and the auxiliary approach is used for clamp operations. (A-B) The first puncture. The yellow arrow indicates the suture hook, the green arrow indicates the suture, the purple arrow indicates the clamp, and the blue arrow indicates meniscus (same as below in the figure). (C) The second puncture. (D) The third puncture. The red arrow indicates the suture (showing one side). (E) The process of the suture going through the loop. The pink arrow indicates the loop, whereas the white arrow indicates the A end of the suture. (F) The 2 ends of the suture are knotted and the suture is pulled out of the bone tunnel.

principles of rehabilitation are almost same as those of traditional meniscal suture surgery. Usually, the patient can begin quadriceps exercises, such as leg lifts, ankle pumps, and knee flexion after surgery. By 4 weeks after surgery, knee flexion to 90° should be achieved. By 6 weeks after surgery, knee flexion to 120° should be achieved. Weight training usually begins at 6 to 8 weeks after surgery. When the range of motion, muscle strength, and flexibility of the affected side are 80% to 90% of the healthy side, the patient can begin to gradually resume sports exercise of the affected knee joint.

Discussion

The meniscus is an important mechanical structure of the knee joint.[12] For obvious meniscus injuries, aggressive arthroscopic surgery is necessary to prevent deterioration of knee function. There are many meniscus suture methods, including the outside-in technique,[13] inside-out technique,[14] and the all-inside technique.[15] The all-inside suture technique is becoming increasingly popular among clinicians. At present, many suture techniques are based on all-inside suture technology. All-inside suture technology can make meniscus repair

Table 1. Pearls and Pitfalls of the Continuous Sewing Machine-Like Suture Technique

Pearls
• An adequate length of suture should be left at the distal end of the hook.
• When multiple punctures are involved in the suture process, the suture should pass through the loop formed, and the puncture location can be designed in real time according to the type of tear to form different shapes of knots. All these measures can enhance the stability of the knots.
• The establishment of the auxiliary approach can be selected according to the location of the suture hook.
• When exiting the suture hook, be careful not to take out the suture.
• For patients with a meniscus root tear or requiring meniscal centralization, more than one high-strength suture can be used. Each suture can be stitched multiple times according to our modified technology.
• The exit and entry points of the suture can be on the same or different sides of the meniscus according to the needs of the procedure.
Pitfalls
• Improper use of the suture hook may cause tissue or suture damage.
• Improper choice of puncture location may result in a decrease in the strength of the knot.
• The establishment of an additional operative approach may cause tissue damage.

Table 2. Advantages and Disadvantages of the Continuous Sewing Machine-Like Suture Technique

Advantages
• Combined with the advantages of suture hook and suture device, continuous sewing machine-like suture technique is realized.
• This technique is suitable for meniscus root tear, complex meniscus tear, and other meniscus surgery, and it can be widely used.
• Multiple consecutive punctures can be completed with a single suture, which significantly saves on the costs of consumables. In addition, our technology is fast and convenient, which can save time.
• Traction sutures can be dispensed with, multiple puncture sites can be achieved, and the knot is strengthened.
• Can be applied to other knee and shoulder arthroscopy surgeries.
Disadvantages
• An additional auxiliary approach needs to be established for the operation.
• Certain technical difficulty is involved.

surgery more minimally invasive, reduce postoperative pain and time in bed for patients, and can help them resume sports as soon as possible. However, the disadvantage of the all-inside suture device technology that cannot be ignored is the poor economy.[11] The sewing machine-like suture technique designed by us combines the convenience of all-inside suture device technology and the low cost of all-inside suture hook technology, which has good practical value.

Pearls and pitfalls of our modified technology are shown in Table 1, whereas some advantages and disadvantages are illustrated in Table 2. It is worth emphasizing that the process we designed enables multiple punctures, and the process of threading the suture through the loop could strengthen the knot. We creatively designed our modified technology by combining the principles of a sewing machine. Suture hooks often are used in arthroscopic shoulder surgery.[16] In recent years, with the popularity of all-inside technology, suture hooks also have been used to suture meniscus.[17] Our technology has important application value in meniscus longitudinal tear repair, meniscus root tear repair, meniscus radial tear repair, and meniscus centralization surgery. However, it should be noted that our technology has certain requirements on the level of the clinician's surgery. The hook can cause accidental tissue damage if not used properly. More details are shown in Video 1. It should be pointed out that our technology can not only be applied to arthroscopic surgery of knee meniscus but also to other knee as well as shoulder arthroscopy surgeries. The application potential is very wide.

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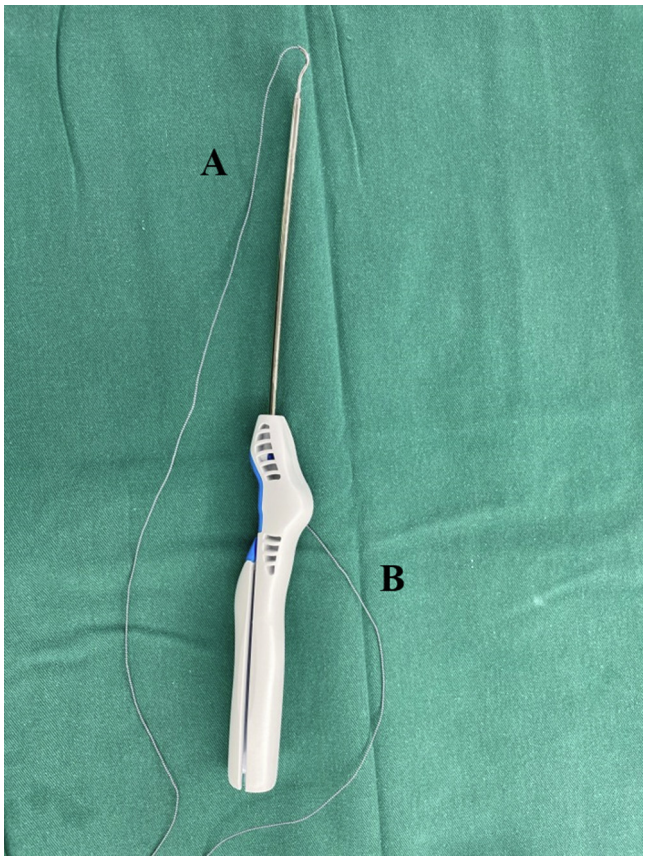
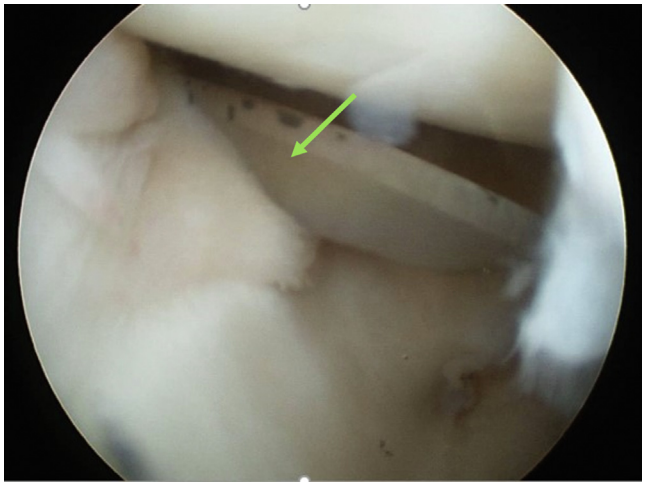


Appendix Fig 1. Display of suture hook directly loaded with high-strength suture. As shown in the figure, similar to suture hook loaded with traction suture, the high-strength suture also needs to leave enough length at the front of the suture hook. Similarly, the A end of the suture represents the free end located at the front of the suture hook, and the B end represents the other free end, as indicated in the figure.



Appendix Fig 2. The establishment of the medial auxiliary approach for arthroscopic perspective. The anterolateral approach is used as an observational approach. The green arrow indicates the surgical blade during the establishment of the medial approach.