

# Biomechanical Study of Meniscal Repair Using Horizontal Sutures and Vertical Loop Techniques

## Abstract

**Background:** Meniscus plays an important role in weight-bearing and energy absorption. Moreover, its function is optimal to maintain joint stability and congruous. Treatments for meniscus damage or meniscus tear include open or arthroscopic repair and meniscectomy. One of the most important factors that influence patients' recovery outcome is restoration technique. The purpose of this study was to compare the strength of recently new method of meniscus repair, submeniscal horizontal sutures, and single vertical loop suturing techniques in meniscus repair. **Materials and Methods:** An experimental study was conducted to study 12 ruptured medial meniscuses of bulls, which were divided into two groups of six meniscuses equally. In this study, submeniscal horizontal and vertical loop suturing techniques were compared based on their resistance to tensile forces and the stability of repaired gaps. **Results:** In this study, submeniscal horizontal and vertical loop knots were  $104.3 \pm 12.5$  N and  $110.7 \pm 16.4$  N, respectively. No significant difference was found between the two groups. To measure the stability of the gap,  $95.4 \pm 8.7$  N tensile force was applied to submeniscal and  $124.6 \pm 11.7$  N to vertical loop techniques. There was significantly different in gap stability between horizontal and vertical loop techniques in meniscal repair ( $P = 0.02$ ). **Conclusion:** The results of this study indicate that knot resistance in submeniscal horizontal is similar to vertical loop resistance. The stability of the restored gap in vertical loop technique is more than submeniscal horizontal techniques. Vertical loop causes greater stability against tensile force.

**Keywords:** Arthroscopy, meniscus, suture

## Introduction

Each meniscus consists of crescent-shaped fibrocartilage that lies between the femoral condyles and the tibial plateau. The meniscal diameter is about 35 mm and it is fixed to the joint capsule by its peripheral margin, which has a length of 110 mm.<sup>[1]</sup> Anterior horn and posterior horn are firmly attached to the bone through ligamentous connections. According to the statistics, meniscal tear occurs to 60–70 individuals/100,000, which makes it common among people.<sup>[1]</sup> Meniscal tear in men occurs four times more than women. Meniscal pathology at younger age and acute trauma and degenerative changes in older ages are the causing factors of meniscal tear. One-third of meniscal tear cases are related to or concurrent with cruciate ligament tear.<sup>[1]</sup> The peak age for men is from 21 to 30 years and for women from 11 to 30 years. Meniscuses play an important role in the function of

the meniscus of the knee. Based on the longitudinal studies, knees with missing meniscus are susceptible to arthritis changes and early osteoarthritis.<sup>[1]</sup> The meniscal function in weight-bearing, energy absorption, joint stability, and joint congruency is crucial. Treatment methods in cases of damage and meniscal tear include total or partial meniscectomy, open meniscus repair, or arthroscopic surgery with inside-out, inside-in, and all-inside methods.<sup>[2,3]</sup> Different repair techniques are introduced, and suture repair techniques caused to superior biomechanical stability.<sup>[4]</sup> Regarding its strength, vertical sutures are commonly considered the gold standard. According to different models, the strength of vertical sutures was found to be in a range from about 60 N to more than 200 N.<sup>[5,6]</sup> Horizontal sutures lie in between the circumferential fiber bundles and yield a lower failure load because they are pulled through those fibers as they are loaded.<sup>[7]</sup> Today, submeniscal horizontal repair is

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**Ali Tabrizi,  
Mohammad Javad  
Shariyate**

*From the Department of  
Orthopedic Surgery, Imam  
Khomeini Hospital, Urmia  
University of Medical Sciences,  
Urmia, Iran*

**Address for correspondence:**  
Dr. Ali Tabrizi,  
Moderres Ave, Imam Khomeini  
Hospital, Urmia University of  
Medical Sciences, Urmia, Iran.  
E-mail: ali.tab.ms@gmail.com

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considered.<sup>[8]</sup> Today submeniscal horizontal suture repair technique has been considered, it is alternative method in meniscus repair. Until now, this technique has not been compared and it is a biomechanical study. In this study, we aimed to compare the strength and stability of two meniscus techniques including submeniscal horizontal and vertical loops.

### Materials and Methods

In an experimental study, a sample consisted of 12 medial meniscuses of 14–16-month-old Holstein bulls was being investigated. The bulls had been growing up in the same farm in a similar situation. Their meniscus was removed for the experiment within 24–48 h after slaughter. All the meniscuses were slotted 3 cm longitudinally with 4 ml away from the edge. The yarn that was used for all the cases in the current study was from the same size and same type. No. 1 polydioxanone (PDS; Ethicon, Somerville, NJ) and a 21-G needle in each technique were used. A tensiometer was used to measure the elasticity and resistance of the knots, and the applied force was measured in Newton. Stability of the gap was considered visually and deformation. Figure 1 shows how to measure the resistance with tensiometer

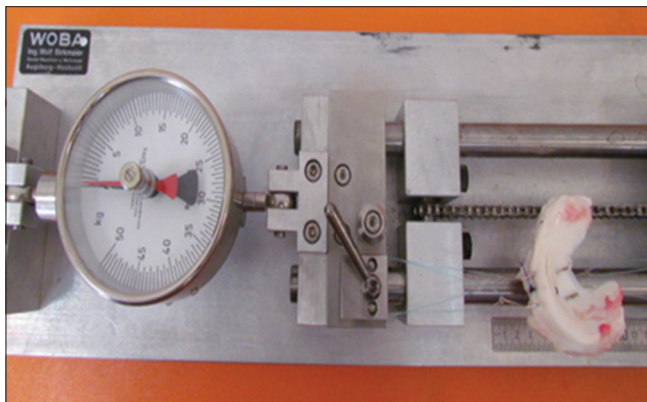


Figure 1: Image shows the force application method and measurement of a knot resistance in the cow's meniscus

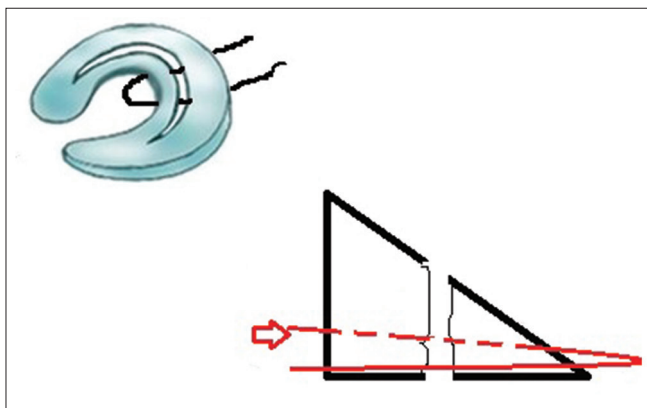


Figure 3: The meniscal lesion was repaired by horizontal submeniscal suture repair

and Figure 2 shows cows' meniscus in comparison with human meniscus.

### Technique

In submeniscal horizontal techniques, suture was passed through the meniscus body horizontally and across the tear and exited from the undersurface of the meniscus [Figure 3]. The suture was advanced until the end of the suture was seen within the joint. The free end of the suture was pulled out through the anteromedial portal using a grasp. Anterior to the entry point, a second cannula threaded with a nylon 2-0 suture loop was passed through the same incision and again exited through the inferior surface of the meniscus.<sup>[8]</sup> Outside the knee joint, the free PDS suture was passed through the suture loop. Pulling on the suture loop from its entry point drew the free suture back into the joint and out of the skin. The two free ends of the PDS suture were then tied with 5–6 simple knots. In single vertical loop techniques similar to submeniscal horizontal, the PDS suture was used. The suture was passed across the tear and vertically stretched out [Figure 4]. After attaching the knobs, we connected the tensiometer and gradually applied force.

For statistical analysis between the two groups, used Mann–Whitney U statistical methods for nonparametric. The SPSS software (Statistical Package for the Social Sciences, version 17.0, SPSS Inc, Chicago, Ill, USA) was used for data analyses and a *P* value less than .05 was considered significant.

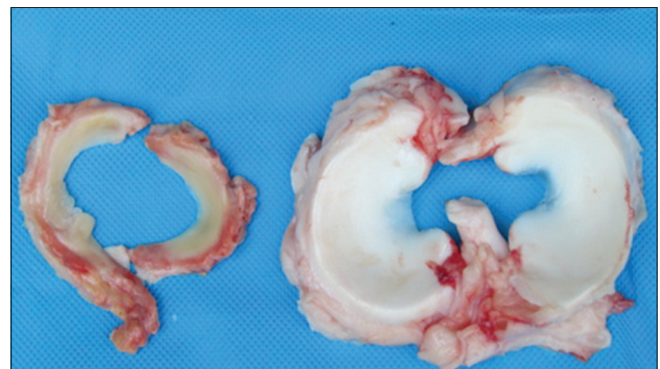


Figure 2: Comparison between the image of a cow meniscus and human meniscus

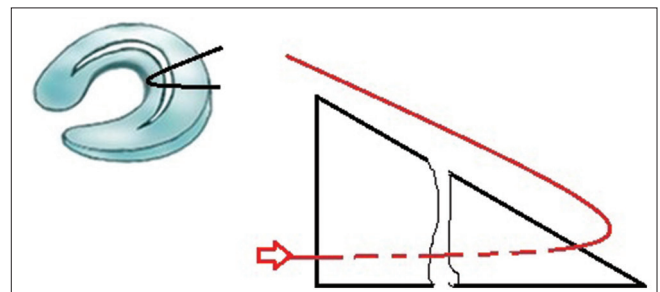


Figure 4: The meniscal lesion was repaired by vertical loop suture repair

## Results

In this study, the submeniscal horizontal and vertical loop stitches had the same resistance to tensile forces, and no significant difference was observed between these two kinds of suturing. However, the stability of restored gap was greater under tensile force in vertical loop suturing than in submeniscal horizontal and statistically significant difference was observed in the field [Table 1].

## Discussion

Meniscal tear usually occurs due to a combination of mechanical forces or without previous meniscus injuries such as degeneration.<sup>[1,2]</sup> Rupture occurs less traumatic if no injuries have already occurred. Several therapeutic procedures have been used for meniscal tear such as meniscectomy and various methods of repairing (3 and 4). Nowadays, specialist's opinions focus on reparation of the damaged meniscus. The full-length tear is the most common types of meniscal tears that need restoration.<sup>[8]</sup> Recovery success depends on many factors such as the techniques that are used in repairing and surgery procedures.<sup>[9]</sup> Meniscus repair could be done using two different techniques including open or arthroscopic methods such as inside-out, outside-in, and the all-inside types. Outside-in and inside-out methods are performed by a simple incision. All-inside methods include different options and multiple nodes and multiple arthroscopic fixtures and various fixation devices.<sup>[10]</sup> Besides restoration methods, suturing techniques for fixing the torn area play an important role in recovery outcome and success. In the past few years, due to the progresses made in science and also amplification of our knowledge, numerous ways of suturing of meniscus have been invented. There is uncertainty in the current literature on the use of vertical and horizontal suturing techniques.<sup>[7]</sup>

Many authors believe that the tension forces have no impact on the horizontal and vertical suturing techniques, and some authors believe that horizontal suturing techniques are less efficient compared to vertical suturing techniques, and rupture in vertical technique is 25% less than the horizontal type.<sup>[7]</sup> A technical problem during meniscal repair in horizontal techniques is placing the sutures in the far posterior region of the meniscus. Submeniscal horizontal suture is a suitable technique to resolve this problem and reach this part of the menisci without any additional incisions. Another issue concerning meniscal repair is the possible abrasion of joint cartilage and synovium by

the repair materials. Parts of the implants that surmount the surface of the meniscus can wear down the cartilage in the contact zones and cause chronic synovitis.<sup>[11,12]</sup> The suture materials placed over the meniscus may abrade the cartilage of the femoral condyles during weight-bearing and range of motion.<sup>[13]</sup> The rationale for using submeniscal sutures is to prevent this potential hazard. In the clinical study by Navali and Aslani, submeniscal horizontal out-in repair technique of meniscus tear in 103 patients had succeeded.<sup>[8]</sup> This technique is cheap, safe, and has the advantage of avoiding chondral abrasion caused by solid implants and suture materials placed over the meniscus.<sup>[8]</sup>

According to an experiment by Boenisch *et al.*, additional force was needed to suture failure for the sutures done with a vertical technique (113.9 N) in comparison with the horizontal techniques (75.1 N) using PDS-0 yarns.<sup>[14]</sup> In addition, Post *et al.* showed in their study on animal models that a 146.3 N force was necessary for suture failure in vertical techniques while in horizontal type a force as strong as 73.8 N was needed. The kind of suture that was used was similar to a previous study (PDS type) and there was no difference in the fabric.<sup>[15]</sup> In this study, for further investigation, Ethibond yarns (2-0 Ethibond) have also been used in addition to the PDS and the same result was obtained; stability of the suture done in a vertical way was greater than horizontal ones.<sup>[15]</sup> According to the study conducted by Fantasia *et al.*<sup>[16]</sup> in 2012 in a laboratory environment on the stencil power of the meniscal suturing, mulberry techniques have high tensile strength in comparison to the horizontal method, and tensile strength of sutures done in mulberry technique was 30 N more.<sup>[16]</sup> In contrast to the findings of the above experiments, Kocabay *et al.*'s study indicates that the average force required to suture that is done with a vertical technique to fail is 145.9 N and in oblique technique is 171.9 N, which are significantly different.<sup>[17]</sup> Based on the findings of our study, vertical loop suturing resistance to tearing is the same and no significant differences have been observed in this matter. The interesting point in our results is the stability of the repaired gap in two different techniques of repairing. So that, the sutures that were done with the single vertical loop technique were more persistent in comparison with those submeniscal horizontal techniques. However in previous studies, vertical loop techniques have more stability against tension and their resistance was greater in comparison with horizontal nodes; according to our study, the aim was to examine both vertical loop and submeniscal horizontal loop techniques which have not been done before and hence our study is unique in this respect. The high resistance of vertical suture was mentioned in two studies conducted by Boenisch *et al.* and Post *et al.*,<sup>[14,15]</sup> and the amount of tensile force needed to fail this vertical sutures was reported to be 150 N which was consistent with the results in our study of vertical sutures. However, vertical loop sutures seemed to have higher persistence

**Table 1: Compare the strength and stability of two types of meniscus repair**

Variable	Submeniscal horizontal suturing	Vertical loop suturing	P
Tear resistance (N)	104.3±12.5	110.7±16.4	0.08
Gap stability (N)	95.4±8.7	124.6±11.7	0.02



since it can tolerate 30 N additional forces and kept their stability under a force up to 180 N. Still, the required force for failing the two types of suture was the same. A similar result was found in a study conducted by Rimmer *et al.*<sup>[7]</sup> on the evaluation of three methods of single horizontal arthroscopic loop knots, double vertical loops, and single vertical loop. The average horizontal force needed for suture failure was 29.3 N, and while this force was greater for a double vertical loop was much more. This difference was statistically significant. In the clinical study by Navali and Aslani, submeniscal horizontal out-in repair technique of meniscus in 103 patients had succeeded. This technique is cheap, safe, and has the advantage of avoiding chondral abrasion caused by solid implants and suture materials placed over the meniscus. In addition, the shape of meniscus repair may affect results of improvement. The three repair methods – the hashtag, crosstag, and cross-suture techniques – were evaluated by Stender *et al.* in radial tears of meniscus.<sup>[18]</sup> Based of Stender *et al.*'s study, two novel repair techniques – hashtag and crosstag – that did not demonstrate superiority in terms of load to failure or stiffness, but both repairs were statistically superior to the cross-suture repair in terms of displacement after cyclic loading.<sup>[18]</sup> In contrary to this, in our study, the cyclic loading force has not been studied in the repair of the meniscus tear, which is one of the weaknesses.

### Limitation of study

Tissue healing and the lost structural integrity to recover in human dependent more factors. Our experiment in two methods of meniscal repair was done in meniscus of bulls, which is essentially (diameter and stiffness) different from humans. For this reason, there may be differences in the amount of tensile strength involved. In this study, the tensile force was applied only to the horizontal plane. In the human's knee and clinical setting, different forces are brought to the meniscus vertically, horizontally, and cyclic loading force.

### Conclusion

The results of this study indicate that knot resistance in submeniscal horizontal is similar to vertical loop. The stability of the restored gap in vertical loop technique is more than submeniscal horizontal techniques. Vertical loop causes greater stability against tensile force.

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### Conflicts of interest

There are no conflicts of interest.

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