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Strength of different meniscus suturing techniques

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Abstract We measured and compared the primary stabilities of five different meniscal suturing techniques. The techniques tested were horizontal mattress, vertical mattress, knot-end, vertical, and vertical loop. Twenty bovine medial menisci were cut to simulate peripheral longitudinal tears and repaired with one of the five suture techniques. Then the two parts of the meniscus were pulled using the Instron Tensometer until failure occurred. Knot-end techniques gave inferior results (mean ultimate failure strength 64 ± 5 N) compared with the other techniques. Vertical mattress failed at 130 ± 3 N, vertical loop at 128 ± 4.5 N, horizontal mattress at 98 ± 5 N and vertical suturing at 136 ± 2.7 N. This study shows the superior mechanical characteristic of the vertical suturing technique.

Key words Suture techniques · Meniscal repair · Biomechanical study

Introduction

The importance of preserving meniscal tissue in the knee is well established. Studies have revealed that the menisci play a significant role in load transmission, shock absorption, lubrication, and ensuring stability and proprioception in the knee [1, 12, 15, 16, 23, 28, 29]. Therefore, meniscal repair is now recommended to treat meniscal tears.

It has been reported that 10%–20% of meniscal tears and 30% of longitudinal tears are suitable for repair [17, 23]. With the correct patient selection, meniscal repair techniques (open and arthroscopic) are 80%–90% successful for either acute or chronic tears [1, 5, 7, 8, 13, 21, 23, 27]. The success rate of the repair depends on the age of the patient, suitability of the tear for repair, stability of the knee, vascularization of the tear rims, abrasion of the synovial surfaces, postoperative rehabilitation and type of suturing technique [19, 26, 29]. This in vitro study compared the strength of five different common suture techniques using medial calf menisci.

Materials and methods

Twenty medial menisci were harvested from 4-month-old calf knees. The menisci were wrapped in saline-soaked gauze and frozen at –20° C until the time of testing. They were soaked in a saline solution at body temperature for 6 h before testing.

The menisci were randomly separated into five groups. Initially, all menisci were longitudinally cut 4 mm from the periphery with a scalpel. A holding suture (2-silk) was, placed with the Kirchmayr technique [18] on the concave side, and another holding suture was placed on the convex side with the same suture material. The testing suture was placed in the middle of the meniscus with 1-prolene and a 40-mm round-bodied needle (Fig. 1). Only one testing suture was used for each meniscus.

Each group, consisted of four menisci. In group 1 horizontal mattress [6], in group 2 vertical mattress [19], in group 3 knot-end (with three knots) [22], in group 4 vertical [18], in group 5 vertical loop [26] sutures were performed. The thread ends were knotted on the menisci (Fig. 2).

The prepared menisci were distracted with an Instron Tensometer (Instron, Canton, Ma; USA). The results were assessed with the force-elongation diagram. The thread length and the connection arm lengths were kept constant. The cross-head speed was 5 mm/min, the chart speed was 20 mm/min. The tests were performed at 25° C room temperature and 100% humidity. We used Student's-test for statistical analysis and gave the results as mean ± 1 SD.

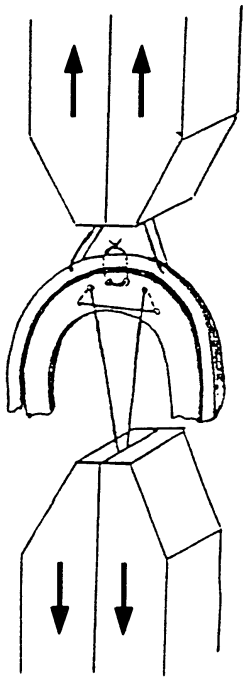

Fig. 1 Attachment by threads of the meniscus to the Instron device

Results

The force-elongation diagram of one example specimen for each group is shown in Fig. 3. The mean ultimate failure strengths for each group were noted (Table 1). According to these results, we found significant differences in the primary stability of all but group 2 and 5 suturing techniques (Fig. 3, Table 1).

The mean tearing stress for the horizontal mattress suturing technique (group 1) was 98 ± 5 N, for the vertical mattress suture technique (group 2) 130 ± 3 N, for the knot-end suture technique (group 3) 64 ± 5 N, for the vertical suturing technique (group 4) 136 ± 2.7 N, and for the vertical loop suturing technique (group 5) 128 ± 4.5 N. Thus, vertical suturing technique has the highest mean ultimate failure strength. The differences between the mean ultimate failure strengths were: group 1 vs group 2, $P < 0.02$; group 2 vs group 4, $P < 0.05$; group 2 vs group 5, $P > 0.05$; and among all other groups, $P < 0.001$.

In group 4, all the threads ruptured. In group 2, in one test the thread was pulled out of the meniscus substance and in the other tests the threads ruptured. In group 5, the threads were pulled out of the meniscus in two tests. In group 1, the threads were pulled out of the meniscus substance in all tests. In the knot-end suture group (group 3) all the threads were pulled out of the meniscus. The silk holding sutures neither ruptured nor pulled out of the meniscus throughout the tests.

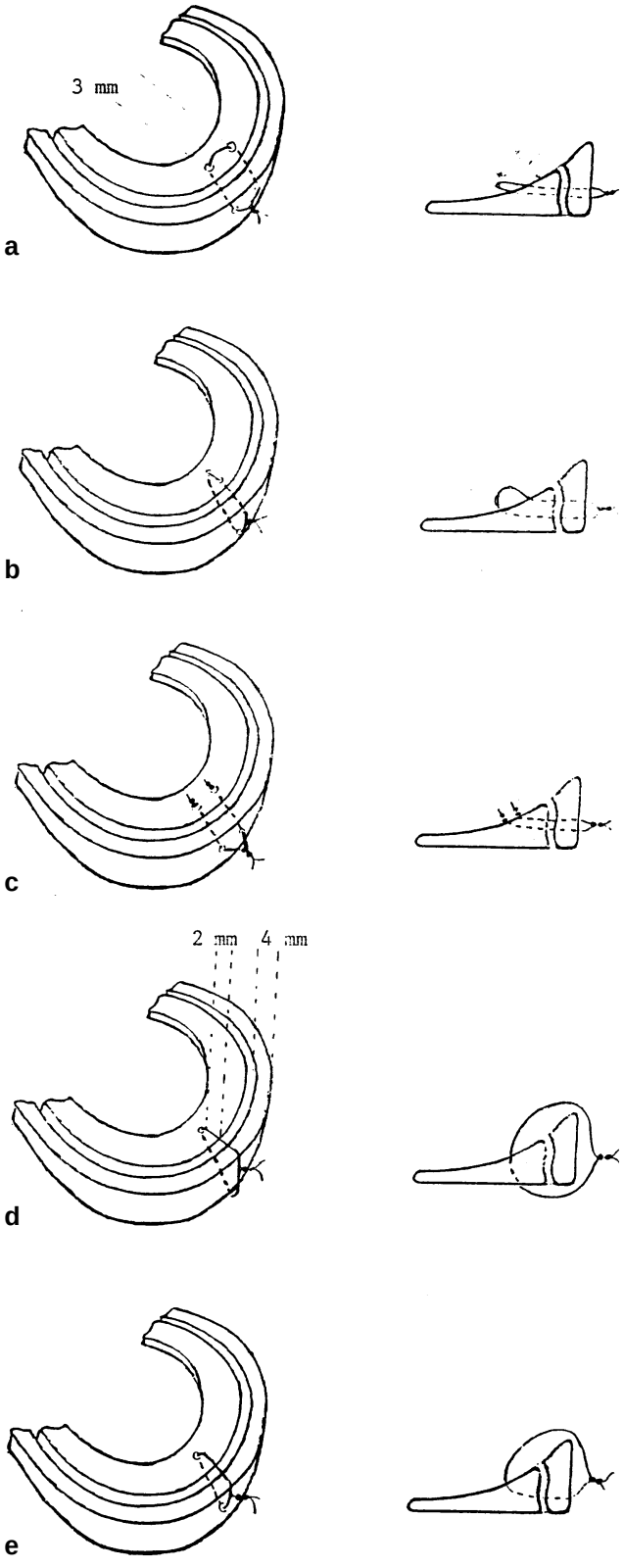

Fig. 2 Suture types: **a** horizontal mattress, group 1; **b** vertical mattress, group 2; **c** knot-end, group 3; **d** vertical, group 4; **e** vertical loop, group 5

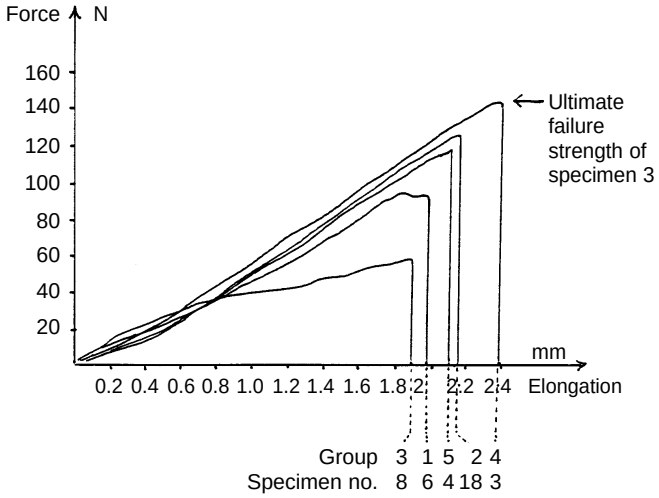

Fig. 3 Force/elongation diagram of one example specimen for each group

Discussion

Recently, the importance of the menisci has been emphasized by several biomechanical and long-term clinical studies [12, 23, 28]. With knowledge of the biomechanics and functional importance of the menisci, meniscus salvaging procedures such as repairs have become favored operations. Meniscus repair can be done by arthrotomy (open) or by arthroscopic techniques [7, 9–11, 13, 14, 21].

Several suture types have been described both for the arthroscopic and open techniques. Generally, the vertical suture technique is performed in open repairs [9–11], while horizontal mattress, vertical mattress and vertical loop suture techniques are performed in inside-out arthroscopic meniscus repairs [4, 6, 29], and knot-end type suture is performed in outside-in arthroscopic meniscus repairs [6, 20, 29, 30].

Although many clinical studies have discussed suturing techniques and types, there are few biomechanical studies in the literature that examine the primary stability of the suturing techniques. A high primary strength of the suture is only one factor contributing to the final result of meniscal repair, but it seems to be advantageous. High strength may hasten postoperative rehabilitation because the meniscus requires less protection. A lower re-rupture rate can be expected if higher strength is achieved.

Kohn and Siebert studied four different suturing techniques in cadaveric menisci. They found that the knot-end technique had the lowest and vertical suturing technique

Table 1 Mean ultimate failure strength of the suturing techniques

Specimen no.	Suture type	Ultimate failure strength (*n*)	Mean values (*n*)	Type of failure
2	Horizontal	103		Torn out of the meniscus
10	mattress	98	98 ± 5	Torn out of the meniscus
6	group 1	91		Torn out of the meniscus
14		101		Torn out of the meniscus
18	Vertical	126		Torn out of the meniscus
5	mattress	131	130 ± 3	Rupture of the thread
20	group 2	130		Rupture of the thread
9		133		Rupture of the thread
19	Knot-end	65		Torn out of the meniscus
1	group 3	70	64 ± 5	Torn out of the meniscus
8		58		Torn out of the meniscus
12		63		Torn out of the meniscus
3	Vertical	140		Rupture of the thread
7	group 4	135	136 ± 2.7	Rupture of the thread
17		138		Rupture of the thread
16		134		Rupture of the thread
11	Vertical loop	132		Rupture of the thread
4	group 5	122	128 ± 4.5	Torn out of the meniscus
13		129		Torn out of the meniscus
15		131		Rupture of the thread

the highest primary stability [18]. Rimmer et al. studied three different suturing techniques and reported that the horizontal mattress technique had the lowest and vertical loop technique the highest primary stability [26].

In contrast, we studied more suturing types and amounts of measures and utilized calf knee menisci as our model. Calf menisci are comparable with human menisci, both in their shape and the arrangement of their collagen fibers [24]. However, they are larger and harder than human menisci. Therefore, the measured values are higher than in the other studies with human menisci. Since the relative comparison is important, we think that this did not influence the significance of our study. We used 1-prolene threads in our tests.

We found that vertically placed suture types had the highest and horizontally placed suture types the lowest primary stability. These findings are compatible with the results of the other studies [18, 26]. Adult menisci consist of 75% collagen fibers, and most of these fibers are circumferential. The radial fibers are less common and are found especially on the surface of the meniscus [25]. Therefore, vertically placed sutures are held with the circumferential collagen fibers, while horizontally placed sutures are parallel to these fibers and therefore more easily pulled through the meniscus. In other words, a horizontal suture pulls out by separating fibers, while a vertical suture would have to transect them. The difference between vertically placed sutures depends upon the size of the meniscus mass that they hold. Since the vertical suturing technique passes through a thicker part of the meniscus, it is specifically supported by a greater amount of circumferential collagen fibers and is thus more stable than the vertical mattress and vertical loop techniques.

On the other hand, one should not forget that the healing of the meniscus does not depend only upon the primary stability but also upon the type of tear [14, 27], the age of the patient, the localization of the tear [2, 27], associated lesions, and the rehabilitation program. Therefore, these biomechanical findings have to be considered as only a single variant of a multivariant equation which influences the clinical outcome.

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