# Mechanical Properties of Meniscal Suture Techniques

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## Content



The human menisci have gained greater appreciation as integral components for normal knee function. The menisci provide shock absorption [18], tibiofemoral load transmission [11], facilitate lubrication with synovial fluid [9], and contribute to knee-joint stabilization [7]. Several clinical long-term studies have shown that total or partial meniscectomy may lead to cartilage degeneration and early onset of osteoarthritic changes [4]. Many orthopedic surgeons, therefore, prefer to repair rather than excise a damaged meniscus whenever possible. Meniscal repair was first performed in 1885 by Annandale [1].

There are several techniques described for meniscus repair such as open repair, inside-out, outside-in, and all-inside [16].

Irrespective of the surgical technique used to access the meniscus, generally four different suture techniques can be used. These are knot-end techniques [10], horizontal, vertical [6], and oblique [8] sutures.

To be effective, a meniscal repair technique should approximate the torn tissue, resist gapping, and be able to withstand the forces associated with rehabilitation and activities of daily living that are initiated before the healing process is complete.

A number of studies have been published examining the mechanical properties of various meniscal repair techniques. These studies generally have used a similar testing methodology. Medial or lateral menisci are obtained from human, porcine, or bovine models. The menisci are usually excised with or without capsule or retain the meniscotibial attachments. Although each of these tissues may enable sufficient representations of time zero mechanical repair characteristics, none of these models match the physiological behavior of the in vivo meniscus [5].

A full-thickness vertical lesion is created in the peripheral third of the meniscus, a few millimeters away from the peripheral edge. Following meniscus lesions repaired, the longitudinal incision was extended completely through the posterior and anterior meniscal horns so that no tissue secured the repair, only the repair devices, representing a worst-case scenario.

In the literature, the failure of the suture techniques generally is considered when the suture ruptures or pulls through the meniscal tissue. In one study, Bellemans et al. [3], using

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human fresh frozen lateral menisci model (with a mean age of 36 years) reported no statistically significant difference in failure load between vertical sutures (46.3 N) and horizontal sutures (52.5 N). They considered failure of meniscal repair when the preset maximum testing time of 700 s was reached, when the suture failed, or when gap opening of more than 3 mm.

Most activities performed by patients over the initial postoperative weeks are repetitive with relatively low intensity loads. Therefore, mechanical test models that use repetitious, submaximal cyclic loading conditions provide a more valid simulation of these activities than ultimate load to failure tests [15]. Basic research studies evaluating the structural properties of meniscal repair constructs should use cyclic testing.

Most biomechanical studies using distraction force tests have reported that vertical sutures for meniscal repair provide superior load at failure compared to horizontal sutures [9, 12–14, 17]; however, other have found no statistically significant difference between the two techniques [3, 15].

Kohn and Siebert [9] published one of the earliest studies on the biomechanical strength of meniscal repair techniques. They reported that significant differences in failure strength among techniques of vertical Vicryl sutures (105 ± 4 N), horizontal Vicryl suture (89 ± 4 N), horizontal Ethibond sutures (44 ± 18 N), and knot-end suture (24 ± 9 N) in their experimental study of an intact cadaveric medial meniscus with a loading rate of 5 mm/min. The mulberry knot technique was significantly weaker than all other techniques. They recommended vertical use.

Rimmer et al. [14], in using a cadaveric lateral meniscus model (with a mean age of 67 years), reported repair failure loads of 67.3 N for vertical sutures and 29.3 N for horizontal sutures. The meniscal repair failure mode for vertical sutures was suture rupture, while horizontal sutures failed by intact suture pulling through the central part of the repair.

Post et al. [12], using a young porcine medial and lateral meniscus model, reported that the load at failure using vertical sutures (146.3 ± 17.1 N) and (115.9 ± 28.5 N) was superior to horizontal sutures (73.81 ± 31.3 N) and (66.1 ± 28.7 N) when 1-PDS and 0-PDS were used, respectively. Additionally, they reported comparable load at failure results for repairs using horizontal sutures regardless if 2–0 Ethibond (59.7 ± 20.4 N), 0-PDS (66.1 ± 28.7 N), or 1-PDS (73.81 ± 31.3 N) suture materials were used [12]. The selected suture material had a much greater contribution to construct fixation when vertical sutures were used, with 1-PDS sutures (146.3 ± 17.1 N) displaying superior load at failure compared to 0-PDS sutures (115.9 ± 28.5 N) [12]. The author recommended that the knee surgeon should consider the relative contributions of suture material to repair integrity when choosing between vertical or horizontal suture methods. While meniscal repair failure using vertical sutures tends to maximize the contributions of the suture material properties to construct integrity, this characteristic has little influence on the fixation strength provided by horizontal sutures.

In their study using a bovine medial meniscus model and 2–0 braided polyester suture material, Rankin et al. [13] reported statistically insignificant and only 19% greater load at failure for vertical (202 ± 7 N) than for horizontal (170 ± 12 N) meniscal repairs. However, they reported that direct suture rupture was the sole failure mode in vertical suture repairs, whereas suture rupture occurred in only 47% (7/15) of the horizontal loop repairs. More of the menisci repaired, using horizontal sutures, failed by suture-loop pullout with intact knots through the meniscal tissue (53%, 8/15). They surmised that tests with a stronger suture material would probably have resulted in significantly greater load at failure results for menisci repaired using vertical sutures.

Asik et al. [2] published a study examining the strength of vertical, vertical mattress, vertical loop, horizontal mattress, and knot-end sutures using 1-Prolene in bovine menisci loaded at 5 mm/min. Although the absolute fixation strengths are higher than those found in cadaveric models, the conclusions are the same. Vertically oriented sutures (approximately 131 N) show significantly higher initial fixation strengths when compared with knot-end (64 ± 5 N) or horizontal techniques (98 ± 5 N). Again, horizontal and knot-end techniques failed by tissue failure, whereas 9 out of the 12 vertical techniques failed by suture rupture.

Kocabey et al. [8], compared pullout strength of vertical, horizontal, and oblique sutures used for meniscal lesion repair using bovine menisci. Suture rupture was the failure mode for all specimens of the oblique suture group. Suture rupture was the failure mode for 57% (4/7) of the vertical suture group with the remaining specimens (3/7, 43%) failing from intact suture pullout through meniscal tissue. All horizontal suture group specimens failed by intact suture pulling through meniscal tissue. Construct stiffness during cyclic testing was superior for the oblique suture (6.9 ± 1.5 N/mm, $P = 0.007$) and the vertical suture (6.4 ± 7 N/mm, $P = 0.03$) groups compared to the horizontal suture at failure for the oblique suture group (171.9 ± 25.9 N) to be 18% greater than that of the vertical suture group (145.9 ± 32.3 N) although both of these suture techniques conceivably captured a greater proportion of circumferential meniscal collagen fibers than the horizontal suture techniques (88.8 ± 8.2 N)

Zantop et al. [19] published a study examining the distraction after cyclic loading, strength and stiffness of vertical and horizontal sutures using 2.0 Ethibond and fresh frozen menisci in distraction and shear force scenarios. In the distraction force scenario, horizontal (4.2 ± 1.5 N) and vertical suture techniques (4.9 ± 1.7 N) showed no statistically significant difference in elongation after 1,000 cycles between 5 and 20 N ($P > .05$). The mechanical behavior of horizontal suture techniques, such as stiffness and yield load, showed no statistically significant difference, whereas the maximum load was significantly higher when compared with the vertical suture technique. Whereas in the shear force scenarios, horizontal suture technique ($2.8 \pm 1.1$ N) showed lower elongation vertical suture technique ($4.6 \pm 2.0$ N) after 1,000 cycles between 5 and 20 N ($P < .05$), horizontal and vertical suture techniques showed no statistically significant difference in maximum load to failure.

Studies of meniscal repair fixation strength generally use the "worst case scenario" condition of distraction loads, applied perpendicular to the repair site. This loading condition, however, does not simulate in vivo meniscal loading [19].

Fisher et al. [5] reported that the shear forces that tend to deform the repaired menisci in vivo differed considerably from most in vitro mechanical laboratory tests. Most meniscal injuries occur secondary to torsional forces with a combined axial knee load. When both torsional and axial knee loads occur, the menisci are subjected to combined shear and compressive forces. Force acting on the meniscus repair site can have both sagittal and coronal plane components resulting in oblique direction shear forces [19].

We need further studies which use shear forces with compressive loads, which mimic in vivo conditions.

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