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# A Biomechanical Comparison of All-Inside Meniscus Repair Techniques

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## Abstract

**Background—**The aim of this study was to assess the biomechanical characteristics of six all-inside meniscal single suture repair techniques using a porcine model.

**Materials and Methods—**Peripheral longitudinal tears were created in freshly isolated porcine menisci. Tears were repaired using the single vertical technique with six different repair complexes including those involving sutures (#2 FiberWire, #2 Ethibone, flexible anchors (Fast-Fix, RapidLoc), and rigid anchors (Meniscal-Dart, BioStinger). Displacement, ultimate failure strength, stiffness, and site of failure were measured using a Materials Testing System machine. An initial 2 N preload was applied, followed by loading between 5 and 20 N for 300 cycles. Failure strength was determined lastly by increasing tension at a rate of 5 mm/min until failure.

**Results—**Failure strength was highest in the #2 FiberWire group (175.6 N). This was significantly higher than in all other groups ($P$ <0.05). The second highest failure load was evident in the #2 Ethibone group (113.8 N). This was significantly higher than in all other groups bar the #2 FiberWire group ($P$ <0.05). Stiffness was also significantly higher in the #2 FiberWire group compared with all other groups (8.5 N/mm, $P$ < 0.05). There were no between-group differences in displacement. When grouped by repair technique, failure load was significantly higher, and displacement was significantly lower, in suture compared with both flexible and rigid anchor repaired menisci ($P$ < 0.01 for all comparisons). Although stiffness was also higher in the suture group, there were no significant between-group differences detected.

**Conclusions—**Suture techniques exhibited biomechanical superiority over biodegradable flexible and rigid anchor devices for meniscus repair.

### Keywords

meniscus sutures; anchors; cyclic loading; porcine

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## INTRODUCTION

Menisci facilitate stability, stress absorption, shock transmission, and load distribution of the knee joint, but are prone to injury [1–4]. The importance of preserving and repairing the meniscus in sports medicine is well recognized. Currently, several repair techniques have been developed, including inside-out, outside-in, and all-inside methods [5–7]. All-inside methods use biodegradable anchors or intra-articular suture techniques, and are associated with decreased operation time. These techniques do not require an additional incision (which may lead to entrapment of, or damage to the neurovascular bundle) and have thus become popular for the repair of menisci [8].

Fast-Fix, Rapid-Loc, BioStinger, and Meniscal Dart are all-inside meniscal repair systems commonly used in the clinical setting [8]. There have been several reports published concerning both the efficacy of these implants in humans [8] and the associated biomechanical characteristics [9]. However, to date there appears to be no consensus as to which technique is most efficacious.

Material Testing System (MTS) machines have been used to approximate loading conditions and study the mechanical characteristics of various meniscal repair devices *in vivo*. Biomechanical strengths of different sutures and techniques have been tested mainly in single menisci. Six different meniscal repair strategies, including two suture techniques (#2 FiberWire, #2 Ethibone), two flexible anchors (Fast-Fix, RapidLoc), and two rigid anchors (BioStinger, Meniscal Dart) were tested in the study. #2 FiberWire is the most recent all-inside suture techniques, while #2 Ethibone has been previously used in both inside-out and outside-in suture techniques. The characteristics of the six repair methodologies, including stiffness, failure load, mode of failure, and displacement were determined and compared.

## MATERIALS AND METHODS

Thirty-six fresh porcine menisci were harvested from the stifle knees of Landrace-Yorkshire-Duroc pigs weighing approximately 120 kg. The peripheral capsule and soft tissues were removed completely early in the morning of the testing day. Two cannulated screws (12 mm × 1.4 mm, Synthes) were inserted into the meniscus. These screws were placed 10 mm apart and inserted to a depth of 1 mm from peripheral edge of the meniscus. Two 0.22 mm surgical wires were placed through the canals of the cannulated screws and securely fastened to the screws by twisting (this facilitated attachment clamping of the test apparatus). A peripheral horizontal incision (similar to a bucket handle tear) was made using a surgical blade on the outer third of the central portion of the meniscus (Fig. 1A). The meniscus was repaired using one of the six implant types (there were a total of six specimens per implant group). All implants were inserted parallel to the undersurface of the meniscus, and perpendicular to the meniscal lesion. Repaired menisci were mounted onto the material testing system (MTS) for biomechanical testing (Fig. 1B). During sample preparation and testing, 0.9% normal saline was used to keep the specimens moist. All procedures were performed by the same investigator.

### Meniscus Repair Devices

Six commercially available implants were tested. These included vertical sutures: #2 Ethibone suture (Ethicon, Somerville, NJ) and #2 FiberWire (Arthrex, Naples, FL); flexible anchors: RapidLoc (Mitek, Westwood, MA) and Fast-Fix (Smith and Nephew, Andover, MA); and rigid anchors: BioStinger Linvatec, Largo, FL) and Meniscal Dart (Arthrex).

**#2 FiberWire and #2 Ethibone—**The same technique (recommended by Arthrex) was used for #2 FiberWire and #2 Ethibone suture repairs. To load the Meniscal Viper, sutures were wrapped around a notch on the tip of the insertion instrument provided. The instrument was

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rotated to facilitate suture twisting relocation to the channel on the back of the instrument tip. The suture was then pulled back and locked in the trigger. The tip of the Meniscal Viper was placed behind the rim of the outer meniscal fragment and across from the artificial lesion. The trigger was then pushed forward and the inner meniscal fragment was pierced 3 mm from the torn lesion. The needle was then advanced through the tissue until a click was felt. This confirmed engagement and capture of the suture by the needle. The suture was then released from the locking slot, the trigger pulled back, and the needle retracted through the tissue to facilitate removal of the Meniscal Viper. The two free suture ends were tied using three fisherman knots (a knot pusher was utilized to maintain suture tension), followed by two manual surgical ties. Cuts were made from 5 mm from the knots.

**Fast-Fix—**The Fast-Fix device contained two 5 mm nonbiodegradable polymer suture bar anchors, with a prettied self gliding knot composed of a nonbiodegradable compound number 0 USP braided polyester sutures. The insertion instrument was placed 3 mm from the artificial lesion, and the inner meniscal fragment was pierced with the needle. The needle was then advanced into the outer meniscal fragment to the end of the depth limiter. After oscillating the needle approximately 5 degrees, the needle was pulled out of the meniscus and implants were released behind the meniscus. The secondary implants were then advanced to the ready position at the end of the needle. The delivery needle was inserted 5 mm from the first implant on a vertical plane. The delivery needle was removed from the meniscus, leaving the free end of the sutures. These were pulled to advance the sliding knot and reduce the meniscal tear. While holding the suture taut, a knot pusher was used obtain the desired tension. A cut was then made from 5 mm from the knot.

**RapidLoc—**The RapidLoc devices consists of three components: (1) a tissue anchor called a “Backstop”, (2) a connecting suture (biodegradable 2-0 nonbiodegradable Ethibond suture), and (3) a second tissue anchor called a “TopHat”, to compress the meniscal lesion against the Backstop. The Backstop was inserted into the curved needle instrument provided and the needle was mounted on the application tool. The needle was placed 3 mm from the artificial lesion and the inner fragment was pierced. The needle was then advanced to the outer meniscal fragment to the end of the depth limiter. The Backstop was deployed by depressing the trigger on the applicator and the needle was removed from the meniscus. The limb of the suture was pulled to ensure capture and fixation of the Backstop. The end of suture was then threaded through the tip of knot pusher, and the pusher was gently moved down the length of the suture while maintaining tension on the suture. The sliding knot and the TopHat were advanced down to the surface of the meniscus. Tension was maintained until the knot was seated in the TopHat and locked in place, allowing the TopHat to just dimple the meniscus. The suture was cut 5 mm from the knot.

**BioStinger—**The BioStinger is a 10 mm bioabsorbable poly-L-lactic acid construct (PLLA), consisting of four rows of barbs. The cannula assembly portion of the 10 mm Hornet delivery system provided was placed into the open loading tray and the trocar needle was advanced through the cannulated implant. The lid of the loading tray was raised to allow cannula to cover the wire and implant until the implant was fully seated in the cannula assembly. The cannula was then retracted by approximately 2 mm by pulling back on the distal control knob to expose the trocar needle. The needle was placed 3 mm from the artificial lesion and the inner fragment was pierced with the needle. The distal control knob was released while the cannula tip was against the meniscus surface, and the handle pushed forward to drive the implant across the artificial lesion. The cannula was advanced until the head of the implant was countersunk into the surface of meniscus. Full deployment was indicated when the distal control knob made contact with the handle.

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**Meniscal Dart—**The 10 mm Meniscal Dart is a double-reversed barbed, noncannulated implant composed of PLLA. A pilot hole was created 3 mm from the artificial lesion in the inner meniscal fragment using a Joystick Trocar provided by Arthrex. The Meniscal Dart was loaded into the tip of the sheath and inserted into the Dart gun, which was attached to the Joystick handle. The sheath was advanced into the pilot hole on the inner meniscal fragment and the trigger of the Dart gun was pulled to drive the Dart 1 mm below the surface of meniscus. The Dart was advanced across the artificial lesion.

### Mechanical Testing

Biomechanical testing was performed using a computer-controlled servo-hydraulic MTS (HT-9102; HungTa, Taichung, Taiwan). Tensile loads were measured with a 50 kgf (1 kgf = 9.8 N) load cell (EMB, Singapore) attached to the crosshead. The specimens were mounted onto the tension load machine and securely fixed by soft-tissue clamping the circling wires of the outer meniscal fragment. Highlighter marking of inner meniscal fragment prevented any slippage of the meniscus tissue between model testing. The load was applied parallel to the implant or suture and perpendicular to the meniscus incision. Each specimen was preconditioned with a preload of 2 N. Following this, 300 cycles, between 5 N and 20 N, were applied at a frequency of 1 Hz. The results of displacement and stiffness were extracted from the computer for statistical analysis. Displacement was defined as the gap between the inner and outer meniscus fragment apparent after cycle loading; while stiffness was given as the load (N) divided by displacement. In clinical terms, higher stiffness and lower displacement result in higher load capacity. Fewer sutures are need with lower displacement, and as a result, healing is hastened. Each sample point was determined from 10 cycle loads, thus there were a total 30 points for each specimen. Finally, meniscal specimens were loaded at a rate of 5 mm/min until failure. Failure was defined as the ultimate strength occurring when the implant or suture was torn out of the meniscal tissue (this triggered the MTS to automatically stop). Six specimens were tested in each group.

### Statistical Analysis

Because the assumption of normality could not be assumed, all data are expressed as median (range). The Kruskal-Wallis test was employed to compare differences among three repair technique groupings (sutures, flexible anchors, and rigid anchors) for each outcome. Differences between all six repair implants were also compared by Kruskal-Wallis test. Post-hoc testing was performed using Hochberg's sequential method with adjusted alpha ($\alpha' = 0.05/$ time of test). A $P$ value of less than 0.5 was considered statistically significant. When multiple comparisons were performed, an adjusted $\alpha$ of (0.05/× test) was used. All statistical analyses were undertaken using SPSS software (version 15.0; SPSS Inc., Chicago, IL).

## RESULTS

A total of 36 specimens were prepared, six for each repair method. All survived a preload of 2 N and 300 cycle loading tests.

Failure was indicated by cutting or tearing of the repaired meniscus tissue or breakage or deformation of the repair device. The results pertaining to failure site and number for each group are presented in Table 1. In the #2 FiberWire group, three specimens failed at the knot level and three at the suture level. In the #2 Ethibone group, four and two specimens snapped at the suture and knot, respectively. All Fast-Fix specimens failed at the sutures of the first pouch. One RapidLoc implant failed at the TopHat anchor, while the other five failed at the suture level. All BioStinger implants failed at the proximal, smooth part of implant engaging the meniscal tissue. Five Meniscal Dart implants failed in the distal half of meniscal tissue due

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to barb angulation, while the remaining implant broke in the middle region. There were no instances of failure due to meniscus tear in any of the experimental groups

Table 2 summarizes the stiffness, displacement, and failure load results for each group. Among the six repair techniques, #2 FiberWire had the highest failure load (175.6 N). This was significantly higher than in all other device groups ($P < 0.05$). The second highest failure load was evident in the #2 Ethibone group (113.8 N); this was significantly higher than in all other groups bar the #2 FiberWire group ($P < 0.05$). Failure load in the Fast-Fix group (68.0 N) was significantly higher than that in the RapidLoc (40.8 N), BioStinger (34.0 N), and Meniscal Dart groups (16.2 N) ($P < 0.05$). The median failure load was significantly higher in the RapidLoc compared with the Meniscal Dart group ($P < 0.05$). Meniscal Dart repaired menisci had the lowest failure load. Stiffness was also significantly higher in #2 FiberWire repaired menisci (8.5 N/mm) compared with all other menisci repair groups ($P < 0.05$). Fast-Fix repaired menisci (4.5 N/mm) exhibited significantly higher stiffness compared with RapidLoc (2.7 N/mm), BioStinger (2.9 N/mm), and Meniscal Dart repaired menisci (2.9 N/mm) ($P < 0.05$). There were no significant between-group differences in displacement following testing.

The results for failure load, displacement, and stiffness as summarized by repair type (suture, flexible anchor, and rigid anchor) are presented in Fig. 2. Failure load was significantly higher in suture repaired compared with both flexible anchor and rigid anchor repaired menisci ($P < 0.001$ for both). Failure load was significantly higher in the flexible compared to rigid anchor grouping ($P < 0.001$). Displacement was significantly lower with techniques involving suture repair compared with both flexible and rigid anchor repair ($P = 0.001$ for both). Stiffness was not significantly influenced by repair technique.

## DISCUSSION

Arthroscopic “all-inside” meniscal repair techniques and devices facilitate surgical ease, are less invasive and risky, and are faster than other techniques [8]. According to the literature, meniscal repair failure rates range from 0% to 43.5% [8]. Use of inadequate repair techniques contributes to such failure. Healing of the surgically repaired meniscus is dependent on multiple factors, such as tear size, location, duration, blood supply, rehabilitation protocol and primary stability, and type of suture technique used [10–12]. The most suitable repair technique for the type of injury should be considered during the procedure. The meniscus may fail, not just as a consequence of a single load, but also in response to repetitive stress. The ideal meniscal repair technique should provide stability of fixation and protect the meniscus from any force encountered during rehabilitation as the wound heals. The MTS allows for testing of repaired menisci under cycle loading that mimic conditions *in vivo*. Hence the outcomes associated with the testing of repair devices are of clinical relevance. Having biomechanical characteristics of the different repair devices at hand may facilitate decision making in the clinical setting.

To match the population in which reparable meniscal tears most often occur, the ideal research tissue should be obtained from fresh, young human cadaver donors. However, the availability of young human menisci is very limited. Various animal models have been used to demonstrate the normal and reparative properties of the meniscus. Material properties of animal implants have been investigated by mimicking physiological behavior relative to that of the human meniscus [13]. Several studies have tested mechanical properties in single meniscus harvested from porcine, bovine, or human cadavers. In the present study, we chose to use porcine meniscus because its size, shape, and structure resemble that of human meniscus. It has been demonstrated that porcine menisci have more consistent mechanical properties than adult human menisci [14]. The porcine meniscus is much thicker at the peripheral rim than the human meniscus. The porcine meniscus also displays minimal deformation and equilibrium

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displacement in response to the viscoelastic creep response compared with bovine and human menisci [13–15].

The purpose of the present study was to uniformly evaluate and compare several key biomechanical parameters following meniscal repair using six different existing devices. Our study was designed to examine consistent pullout strength, with a single vertical suture or one implant under a preload of 2 N, followed by 300 cycles (1 Hz) of loading of between 5 and 20 N with a crosshead speed of 5 mm/min. This is consistent with the parameters used in several previous studies [16,17]. The slow loading rate responses during early rehabilitation exercise and the activities of daily living probably cause equivalent loading forces between the medial meniscus under the anterior cruciate ligament of the knee [18].

No standards have been described regarding cycle number and force for the testing of meniscal repair techniques. Cycle numbers ranging between 1000 and 1500 cycles are thought to correspond to the stress applied within 1 wk of postoperative physical therapy with a stable anterior cruciate ligament [19]. In a study performed by Borden *et al.*, Fast-Fix and conventional sutures in human menisci survived 500 loading cycles of between 5 and 50 N, and a crosshead speed of 5 mm/min [20]. Rigid anchor repaired menisci, however, failed. A displacement of 50% was observed in Fast-Fix repaired menisci during the first 100 cycles; however, there was no significant difference in displacement between 100 and 1000 cycles of loading. In the present investigation, loading was limited to 300 cycles on the premise that this is the most critical period for the meniscus repair complex after repair. Therefore, this should provide the most pertinent information regarding the biomechanical properties. We used a single vertical suture because it is well known that the strength of the vertical loop suture is superior to that of the horizontal suture due to the perpendicular orientation of the meniscal fibers relative to the repair device [21].

We used the same method of repair with #2 FiberWire and #2 Ethibone. Although there were significant differences between the two repair techniques in terms of stiffness (median values were 8.5 and 2.2 N/mm, respectively) and ultimate strength (median values were 175.6 and 113.8 N, respectively), there was no difference in displacement. For both techniques, the sites of failure were either at the thread itself or the knot.

Of the flexible anchor meniscus repair devices, Fast-Fix repaired menisci failed at the knot of the suture in the first pouch of the vertical repair, while RapidLoc repaired menisci failed due to rupture at the suture. These findings are similar to those reported in previous investigations [16,17,20]. The median Fast-Fix failure load was found to be 68.0 N in our study. This was less than the 104.0 N reported by Borden *et al*. following testing with Mersilene tape [20], and the 106 N by Zantop and colleagues after metal clamp testing [17]. We found the median RapidLoc failure load to be 40.8 N. This was also similar to the 30.3 N found in Zantop's study [17]. Although the stiffness of flexible anchor repair devices was lower in our study than in the aforementioned investigations, we reached the same conclusion that the overall properties of Fast-Fix were superior to those of RapidLoc [22,23]. This is most likely due to design differences. Namely, the twist-like U design of the Fast-Fix device (with a cross bar at each side) offers more secure fastening of the meniscus. In contrast, only a single suture fastens the meniscal tear with the RapidLoc device.

Precisely how the degree of displacement and the magnitude of stiffness affect meniscal healing is not known. The stiffness of a device confers stability to the repaired menisci and allows for minimal deformation, which is necessary for tissue healing. In this study, menisci repaired with #2 FiberWire suture exhibited the greatest stiffness (median = 8.5 N/mm), followed by those repaired using the Fast-Fix technique (median = 4.5 N/mm). The rigid repair anchors, BioStinger and Meniscal Dart, exhibited identical stiffness (2.9 N/mm) and similar

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displacement (7.2 and 7.3 mm, respectively). Failure strength, however, was higher in BioStinger repaired menisci (34.0 N *versus* 16.2 N in Meniscal Dart repaired tissues). The inferior pullout strength associated with the rigid anchor techniques may be attributable to both the conical shape of the head of the implant and the shallow barb depth (0.2 mm), resulting in weak engagement within the tissue. Our results pertaining to BioStinger stiffness differ from those of Becker and colleagues [9], where a mean of 15.0 N was reported. The BioStinger failure load in our study (median = 34.0 N) is similar to that noted by Barber *et al.* (56.6 N) in a comparable study [5].

It is not known what exact fixation strength is required to facilitate satisfactory meniscal healing. It seems likely that only relatively low radially directed forces impact on the meniscus *in vivo*. Examination of the stiffness associated with meniscal repair techniques allows some conclusions to be made regarding fixation stability during knee loading. High stiffness and low displacement are required to provide stability for meniscus healing, however, excess strain at the meniscus repair complex may in turn influence tissue healing or lead to implant failure. The rigid anchors show comparable results in terms of tissue healing due to decreased deformation before implant failure. In the investigation of Kirsch and colleagues, the loading forces exerted on repaired menisci did not exceed 10 N [23]. This is far less than the tension load experienced by human meniscal tissue, reported by Wirth *et al.* to be 125 N [24]. This is similar to ultimate loads associated with #2 FiberWire (median = 175.6 N) and #2 Ethibone (median = 113.8 N) meniscal repair in this study.

Healing and remodelling of meniscal tears is dependent on location of the tear, vascularity, and subsequent physical therapy. It is possible that different repair devices may influence remodelling (particularly that related to vascularization) to differing extents *in vivo*. To our knowledge, there have been no studies published where remodelling has been compared with reference to meniscus tear repair technique. This is certainly an issue that warrants consideration in future studies.

This study has a number of limitations that warrant mention. First, precautions should be taken in interpreting the test results as porcine meniscus has less deformation and higher aggregative properties than human meniscus. The different results between the sutures, flexible, and rigid anchor groups may have limited clinical relevance due to the different composition and characteristic according to the Kruskal-Wallis H test between the three techniques group. We also note that these tests were performed on healthy menisci, whereas in reality, meniscal tears frequently occur in degenerated menisci that do not have the same mechanical strength as healthy/normal menisci. In addition, the load force applied parallel to the fixation device does not exactly reflect the multidirectional forces encountered *in vivo* and the crosshead speed was far lower than would occur with actual knee movement. The pitfalls related predominantly to arthroscopic all-inside repair techniques, including intra-articular deployment, suturing tension, and difficulty in placing the vertical suture and knotting could affect the results of testing and clinical outcomes. Finally, we tested menisci strength immediately after repair in this study. In an *in vivo* setting, it is possible that differential device-specific degradation or migration during healing may lead to complications that reduce repair strength. Hence, short-term efficacy may not necessarily be indicative of long-term efficacy when considering failure strength.

## CONCLUSIONS

Vertical sutures have biomechanical properties that are superior to those associated with rigid and flexible anchor techniques for meniscus repair. The vertical suture techniques provide the most rigid fixation that is essential for meniscal tissue healing.

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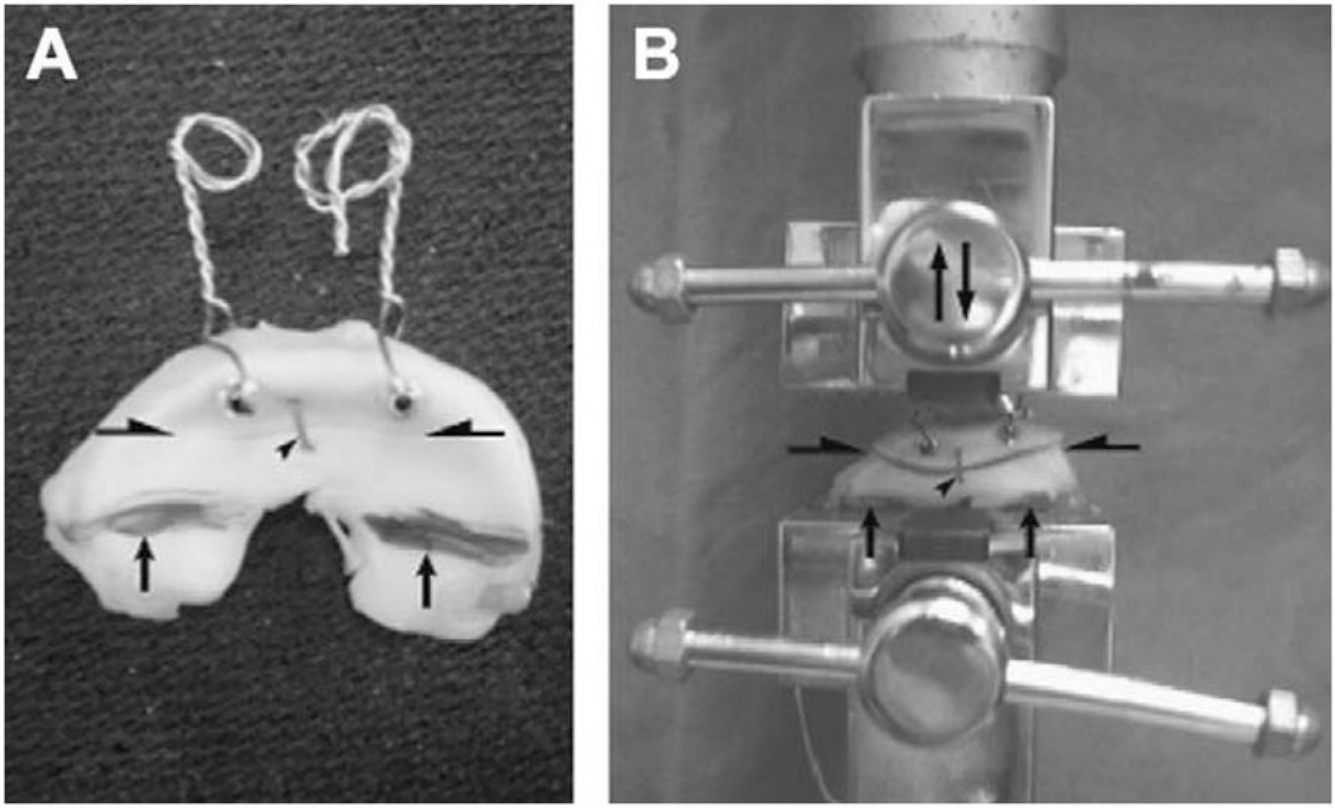


**FIG. 1.**

(A) Two cannulated screws (12 mm × 1.4 mm) were inserted into the meniscus. These screws were place 10 apart and inserted to a depth of 1 mm from peripheral edge of the meniscus. Two 0.22 mm surgical wires were placed through the canals of the cannulated screws and securely fastened to the screws by twisting (this facilitated attachment clamping of the test apparatus [up-pointing arrow]). A peripheral horizontal incision ([left pointing arrow], similar to a bucket handle tear) was made using a surgical blade on the outer third of the central portion of the meniscus. The tear was repaired using one of six techniques. All implants were inserted parallel to the undersurface of the meniscus (filled triangle), and perpendicular to the meniscal lesion. (B) Repaired menisci were mounted onto the material testing system for biomechanical testing. After mounting, menisci were securely clamped and the cyclic loading testing initiated at forces between 5 and 20 N. The arrows (up-pointing arrow and down-pointing arrow) indicate the direction of cycle loading.

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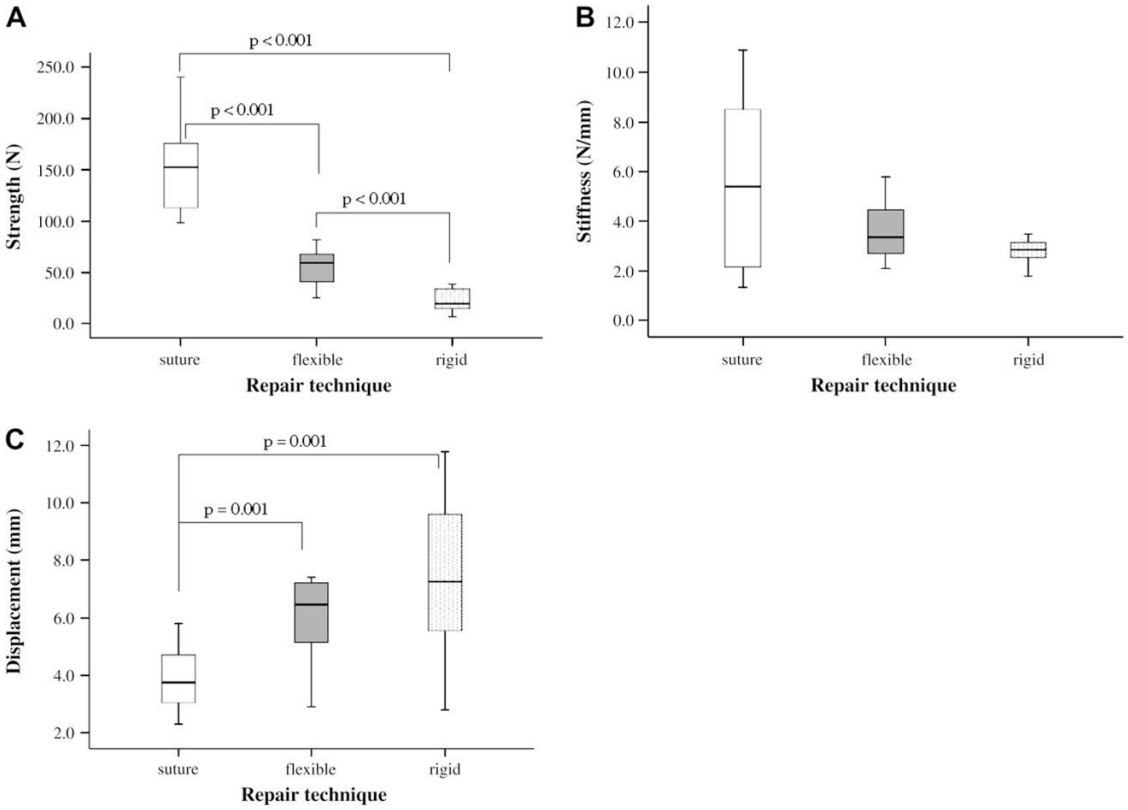


**FIG. 2.**

The experimental results pertaining to (A) failure load, (B) stiffness, and (C) displacement for the three repair types (suture, flexible anchor, and rigid anchor). The median, the first quartile, and the third quartiles are shown. Between group differences were determined using the Kruskal-Wallis test. Hochberg's sequential method with adjusted $\alpha'$ ($\alpha' = 0.05/\times$ test) was used for post-hoc analysis.

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**TABLE 1**

Summary of Failure Sites for Each Repair Technique Following Biomechanical Testing

| Repair technique | Failure site | Number (%) |
|---|---|---|
| #2 FiberWire (*n* = 6) | Suture | 3 (50.0) |
| | Knot | 3 (50.0) |
| #2 Ethibone (*n* = 6) | Suture | 4 (66.6) |
| | Knot | 2 (33.3) |
| Fast-Fix (*n* = 6) | Suture | 6 (100.0) |
| RapidLoc (*n* = 6) | Suture | 5 (83.3) |
| | TopHat | 1 (16.7) |
| BioStinger (*n* = 6) | Non-barbed | 6 (100.0) |
| Meniscal Dart (*n* = 6) | Distal barbed | 5 (83.3) |
| | Middle | 1 (16.7) |

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## TABLE 2

A Summary of the Biomechanical Characteristics (Displacement, Stiffness, and Failure Load) for the Six Types of Meniscus Repair Techniques Tested[1]

| Repair technique | Repair device | Failure load (N) ($n$ = 36) | Stiffness (N/mm) ($n$ = 36) | Displacement (N/mm) ($n$ = 36) |
|---|---|---|---|---|
| Sutures | #2 FiberWire | 175.6 (160.8, 240.5) | 8.5 (6.8, 10.9) | 3.6 (2.8, 5.2) |
| | #2 Ethibone | 113.8 (98.5, 144.2)* | 2.2 (1.4, 4.0)* | 4.2 (2.3, 5.8) |
| Flexible anchors | Fast-Fix | 68.0 (63.5, 82.1)*,† | 4.5 (3.5, 5.8)* | 6.4 (2.9, 7.3) |
| | RapidLoc | 40.8 (25.3, 55.1)*,†,‡ | 2.7 (2.1, 3.2)*,‡ | 6.5 (4.6, 7.4) |
| Rigid anchors | BioStinger | 34.0 (14.3, 38.7)*,†,‡ | 2.9 (1.8, 3.2)*,‡ | 7.3 (5.4, 11.8) |
| | Meniscal Dart | 16.2 (6.7, 25.7)*,†,‡,§ | 2.9 (1.9, 3.5)*,‡ | 7.2 (2.8, 11.3) |

*Note*. Data are presented as the median (range).

[1] Kruskal-Wallis test was used to test the difference among six repair devices; Hochberg's sequential method with adjusted alpha ($\alpha' = 0.05/\times$ test) was used for post-hoc testing.

* Statistically different between the indicated repair device and #2 FiberWire.

† Statistically different between the indicated repair device and #2 Ethibone.

‡ Statistically different between the indicated repair device and Fast-Fix.

§ Statistically different between the indicated repair device and RapidLoc.