Comparison of Suture Types and Techniques in Achilles Tendon Repair: An Ex Vivo Biomechanical Animal Experiment

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Background: Ideal suture technique and type in tendon repair are remain unclear. This biomechanical study aimed to assess the biomechanical characteristics of three techniques, modified Kessler (mKE), modified Krackow (mKR), and modified tension Bunnell (mtBU), in sheep Achilles’ tendon tear repair using three suture types, polypropylene, polyester, and ultra-high molecular weight polyethylene (UHMWPE) sutures, which are also compared.

Methods: Sixty-three Achilles’ tendons harvested from sheep were transversely hacked as a replacement for rupture in a standardized measure and repaired using mKE, mKR, and mtBU techniques with No. 2 polypropylene, polyester, and UHMWPE sutures. Biomechanical parameters, such as Young’s modulus, ultimate strength, and strength to the 5-mm gap were recorded for statistical analysis.

Results: The mtBU technique with UHMWPE use resulted in increased ultimate strength, strength to 5-mm gap, Young’s modulus, and quantity of specimens with low clinical failure modes compared to other techniques with other suture materials. Furthermore, mtBU has the lowest thickness at the repair side of the tendons. This approach showed tendon failure during
maximal traction testing, whereas the mKE and mKR had polyethylene and polyester suture failures.

Conclusions: The UHMWPE suture was significantly superior to the other sutures in each suture techniques in terms of strength and durability. The mtBU technique using UHMWPE suture showed better biomechanical results, implying that this repair might be more appropriate to obtain early mobilization after tendon ruptures.

The Achilles tendon is the thickest and strongest tendon in the human body and is one of the most frequently ruptured.[1] Although surgical tendon repair is often indicated, the ideal suture technique remains controversial.[2, 3] The modified Krackow, modified tension Bunnell, and modified Kessler techniques are well-known tissue-grabbing sutures used in open and percutaneous Achilles’ tendon repairs, and their usefulness has been proven in various biomechanical and clinical studies. The resistance to gap development is critical when utilizing these sutures for tendon and ligament restoration. There will be an increase in granulation tissue, adhesions, and delayed collagen maturation if there is a gap in the healing. The larger the gap, the delayed healing and the result is a weaker, more attenuated repair. Within these current techniques, the technique that minimizes gap formation is the modified tension Bunnel. Although the highest tensile strength was achieved with the Krackow suture technique, the bulkiest tendon reconstructed ends will be occurred with also it. On the

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contrary, the modified Kessler suture technique has the least bulkiness at tendon reconstruction ends among the others.[4-6]

In order to achieve favorable clinical results in tendon repairs, the qualities of suture materials are just as crucial as the repair techniques themselves; nevertheless, several types of sutures have been modified to meet varied requirements in clinical situations. An optimal tendon repair suture should have sufficient tensile strength throughout the critical healing phase, good knot security and handling properties, a low and tolerable foreign body reaction, and better tissue regeneration.[7]

Suture in the No. 2/0 to No. 5 range is advised for Achilles’ tendon repair, depending on the repair technique,[8,9] with braided non-absorbable polyester and monofilament absorbable polyglactin sutures being two of the most widely used materials in Achilles’ tendon repair.[10]

Ultra-high molecular weight polyethylene (UHMWPE) suture is a non-absorbable braided surgical suture prepared from fibers of UHMWPE.[11] Moreover, UHMWPE is a subset of thermoplastic polyethylene and has extremely long chains. They are strong and their softness and chemical inertness minimize tissue inflammation and irritation in applications.[12]

Reconstructions of Achilles, patellar, and quadriceps tendon ruptures often cause serious difficulties for surgeons as they also affect the flexion mechanisms of the lower extremity. Although surgical tendon repair is often indicated, the ideal suture technique and type remain unclear. Suture pullout and/or rupture, gap development, and knot failure were all

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clinical failure types in tendon repair surgeries including suture materials, and they were all related to the mechanical characteristics of the sutures compressively. Moreover, the functional outcomes of tendon repair surgery are strongly influenced by the surgical suturation technique. Hence, it is essential to investigate the best combination of suture technique and type in a biomechanical aspect.

Using three distinct suture materials, polypropylene, polyester, and UHMWPE, this study aimed to analyze and compare the efficacy of mtBU, mKe, and mKR methods in terms of their biomechanical characteristics in a sheep Achilles' tendon repair model.

Methods

Study Design

Sixty-three male sheep Achilles’ tendons were harvested from sheep butchered for commercial purposes at a local slaughterhouse. At the time of slaughter, the sheep were between one and one and a half years old and weighed between 60 and 72 kg. A muscle–tendon junction proximally and a portion of the bony calcaneus, including the enthesis area distally, were found in each specimen. They were immediately frozen to a temperature of 24°C after gathering until the experiments were completed. Each specimen was gradually frozen and kept hydrated at room temperature (about 18°C) for 12 hours prior to the surgical intervention. After biomechanical testing, all specimens were getting rid of according to the Republic of Turkey.

A comparative study with block randomization was conducted. The tendon specimens (n = 63) were first allocated numbers at random. Tendons were then randomly assigned to one of three surgical technique groups (mKR, mKE, and mBU) with three subgroups under each group (polypropylene, polyester, and UHMWPE sutures). Each subgroup consisted of seven specimens. Three surgeons with similar training and clinical expertise used all three surgical procedures to execute timed tendons repairs. The first surgeon deals with the mKE technique with three different types of suture material, the second one deals with the mBU technique with three different types of suture material, and the third one deals with the mKR technique with three different types of suture materials.

Specimen Demographics and Preparation

One senior research assistant of Veterinary Anatomy, DVM and a specialist experienced at slaughterhouse veterinary, DVM were inspected the specimens and specimen taken sheep via macroscopic evaluation to ensure that there are no tendon pathologies just after they are slaughtered before freshly frozen. The length from the calcaneal enthesis to musculo-tendinosis junction of the tendon and distal and proximal distances of the narrowest part of the tendon that was planned to divide sharply into two in the transverse plane replicating rupture with a
No. 11 scalpel blade were measured with a digital caliper and marked in each specimen. The suture needle’s entry and exit sites, based on the used surgical technique to which sample was allocated, were marked. Then surgical repair performed as shown at Figure 1a-c.

Each specimen’s repair bulkiness volume was determined by calculating the native tendon diameter and volume, then passing the native tendon through an anterior cruciate ligament graft sizing guide block and repairing it. The block’s dimensions are preset in 0.5 mm increments; the best size was selected to decide the repair bulkiness. Due to the wide variation in tendon diameters and morphologies between samples, these values are represented as ratios. To compare tendon cross sectional area for three types of suture techniques, calculation was performed by dividing the repaired site’s cross-sectional area by the pre-sutured adjacent proximal and distal parts of one of each specimen. This was performed to standard quantify which tendon saturation was bulkiest (Figure 1c). The cross-sectional area (CSA = \( \frac{W \times H}{4} \times \pi \)) of each tendon was calculated using the following formula:

\[
CSA = \frac{W \times H}{4} \times \pi ,
\]

where the width (W-mm) and height (H-mm) were obtained from measurements by an electronic gauge (CH-10-AT, Liuling, PRC) before and after suturing.

**Surgical Techniques**

All surgical operations were performed by three orthopedic foot and ankle surgeons. The mKE technique is a gripping suture technique in which a single loop of suture encircles the tendon.

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The suture was placed 1 cm proximal and distal to the rupture on both sides. To produce an end-to-end repair, the sutures are tightened and tied in a series of double and five knots. Three locking loops were put 1 cm from either side of the rupture in the mKR procedure. To achieve end-to-end repair, the loops were tightened and knotted with one double and five knots in a row. Interlacing sutures are used in the mtBU technique. A zigzag stitch is used to repair both sides of the torn tendons. One centimeter on either side of the rupture, three loops were put. To achieve end-to-end repair, the loops were tightened and knotted with one double and five knots in a row. To examine the biomechanical properties of two-strand core sutures and the bulk of the repair side of the tendon, no epl tendonious suture augmentation was performed in any specimen (Figure 2a-c).

As the modified versions of the original suture techniques used in this research, mKE, mKR, and mtBU which had two strands crossing with knots located between the ends of the tendon repair site for mKE and mtBU and four strands crossing with knots located between the ends of the tendon repair site for mKR were illustrated at Figure 2a-c.

**Mechanical Testing**

All of the tests were carried out in a controlled environment (temperature of 20 ±1°C; relative humidity of 50%). A universal testing apparatus (Z100, Zwick/Roell GmbH; Ulm, Germany) with testXpert II version 3.2 software was used to conduct biomechanical testing. Two custom-made
tendon clamps were used to mount specimens on the testing system, which were primed with a force of 10 N before the test and subsequently loaded to failure at a displacement rate of 20 mm/min (Figure 1e, f). The ultimate strength (US) and strength to a 5-mm gap were determined using stress–strain curves. The testing device software was used to calculate the Young’s modulus (YM) values. After completion of the biomechanical tests, the fault location and mode in each sample were macroscopically identified and recorded.

During biomechanical testing, the maximum load delivered before a steep fall leading to failure is referred to as the US.\textsuperscript{[14]} The magnitude of displacement was ignored in these measurements. The quantity of load required to establish a 5 mm gap at the repair site is known as strength to 5-mm gap. This is a critical criterion for attaining tendon regeneration close to its original length and determining the top limit for tolerable tendon elongation.\textsuperscript{[15]} The measure of elastic deformation of materials under load is YM, which is defined by the slope of the stress–strain curve.\textsuperscript{[16]}

Statistics

All measurements of all specimens, including the tendon dimension measurement and measurement of tendon repaired bulk, were repeated twice with an interval of 1 h by two orthopedic specialists with five years of professional experience, and intra- and inter-observer
reliabilities were evaluated. Two-way mixed effects model was used to evaluate the agreement and differences between intra- and inter-observer measurements.

Statistical analysis to investigate differences between the groups was performed using IBM SPSS version 21.0 software. The Shapiro-Wilk test showed normally distributed data; homogeneity was verified by analysis with the Levene test. One-way analysis of variance, Tukey’s test, and t-test were performed for multiple and independent group comparisons, and pairwise comparisons respectively. A P-value < 0.05 was considered statistically significant.

Results

In terms of mean specimen dimensions (length, width, and thickness) and biomechanical parameters (US, strength to 5-mm gap, and YM), the three groups with three subgroups were compared (Table 1). Tables 2 and 3 show the distribution of failure mechanisms in the groups, as well as comparisons of the three repair strategies and three suture materials.

Two-way mixed effects model was used to evaluate the agreement and differences between intra- and inter-observer measurements. They were evaluated with intraclass correlation coefficient (ICC). The intra- and inter-observer reliability was determined as excellent (ICC, 0.905–0.976) and good (ICC, 0.889–0.991), respectively, in all steps of specimen preparation before biomechanical testing.

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US

The mtBU-UHMWPE group had the highest mean value in the US, although it was not statistically significant (p = .03). (Table 1). For both the polypropylene (p = .15) and polyester sutures (p = .95), the differences between the repair groups were negligible. In each suture technique (mKE p = .024, mKR p = .044, and mtBU p = .047), the UHMWPE suture was significantly superior to other sutures (mKE p = .024, mKR p = .044, and mtBU p = .047), while the polyester suture was superior to the polypropylene suture without statistical significance in the mKR (p = .33) and in the mKE technique, however, the polyester suture was statistically superior than the polypropylene suture (p = .017) (Figure 3a & f)

Strength to 5-mm Gap

The mKE–UHMWPE group had the highest mean strength to 5-mm gap value (p = .003). (Table 1). The suture technique groups were ordered in descending order of strength to 5-mm gap mean values in UHMWPE suture repairs, and the difference between the suture method groups was statistically significant (p = .022). The difference between groups in polypropylene sutures was statistically insignificant (p = .32). The UHMWPE suture was considerably superior to other sutures in the suture technique groups in terms of strength to 5-mm gap mean values (p = .001).
The mean YM value for the mtBU-UHMWPE group was the highest ($p = .007$). The groups were sorted in descending order of YM mean values as mKR, mKE, and mtBU procedures in polypropylene repairs, and a statistically insignificant difference ($p = .38$) was found. The difference between groups in polyester repairs was also statistically insignificant ($p = .33$). In mKE repairs, the polyester suture outperformed the polypropylene suture by a statistically significant margin ($p = .023$). (Figure 4a-f).

**Discussion**

For almost all variables related to mechanical and dimensional properties, UHMWPE also has favorable results for the mtBU technique. mtBU technique using UHMWPE seems to be a good alternative surgical solution for Achilles’ tendon repair biomechanically.

The ideal tendon repair should be biomechanically reliable to enable early range of motion (ROM) exercises, be easily performed, minimize injury to vascular supply of the tendon, and not be bulky to provide smooth gliding of the tendon.\textsuperscript{[17, 18]} Many different suture techniques have been developed to minimize this bulkiness. Among these suture techniques, Kessler, Bunnel, and Krackow techniques are the most frequently used.\textsuperscript{[19, 20]} In this study, when three different suture materials, polypropylene, polyester, and UHMWPE, are used in each of

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these techniques, the lowest bulkiness was obtained in mtBU surgical technique, UHMWPE suture material, and mtBU technique with UHMWPE.

It is critical that a tendon repair suture should not fail prematurely before reaching strength values close to the suture material’s simple straight pull test yield values. Suture failure by pullout is an example of premature failure since the suture does not break, indicating that the force required to fail is less than the suture material’s yield strength.\textsuperscript{18} Suture breakage adjacent to the knots is another example of premature failure since knots create a weak point in the suture.\textsuperscript{21} In all techniques and suture materials evaluated in this biomechanical study, UHMWPE suture material was observed with pullout from the proximal mode of failure in only two specimens in a total of 21 specimens in all applied techniques. This biomechanical finding has led to the assumption that it may reduce the rate of re-rupture observed especially after Achilles tendon open surgery because, in a prospective, randomized study conducted by Cetti et al., the rupture rate was calculated as 1.4\% (range, 0\%–7.1\%) after surgical treatment (0.7\% after simple end-to-end repair) and 13.4\% (range, 3.9\%–50\%) after conservative treatment.\textsuperscript{22} Lo et al. found a rupture rate of 2.8\% in patients who underwent surgical treatment and 11.7\% in patients who were followed conservatively in their study.\textsuperscript{23}

Another hugely influential biomechanical study, conducted by McCoy et al., discovered that there was no significant difference in strength between the Krackow, Bunnell, and Kessler...
suture techniques when performed with a double suture weave in a laboratory model of cadaveric Achilles’ tendon repairs. This work that seems to negatively basically supports the current study. In our study, when the US parameter was examined, a statistically significant difference was found between the mKR, mtBU and mKE suture techniques. The reason for using modified techniques in our study was based on McCoy et al.’s study.[24]

The recent advancement of UHMWPE suture material, as well as its use in meniscal and rotator cuff repair techniques, is notable. Sutures and suture-based repair devices utilized in meniscal and rotator cuff repair in the past were more likely to break during tensioning and knot tying.[25, 26]

One of the main goals of treatment in Achilles’ tendon ruptures is to enable the patient to return to work as soon as possible. Another goal that applies to many patients is to return the patients to the sports level they had before the injury. The most important factor in achieving this is early rehabilitation. The most important complication that develops in the early postoperative period in patients is the factor affecting the most morbidity, providing almost complete ROM in the ankle joint can only be through early rehabilitation and weight-bearing. The key to early rehabilitation is surgery performed with biomechanically reliable, robust suture material. Postoperative treatment after classical Achilles’ tendon surgical repair consists of immobilization in a cast for six weeks without weight. During this period, the ankle joint ROM is restricted, and this increases the time for the patient to return to work and return to the sports

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level they had before the injury. Costa et al. compared the immobilization protocol with a six-week cast with a carbon-fiber ankle orthosis (1.5-cm heel support) and early weight group in a randomized prospective study of 48 patients. In the early weight group, they found shortened normal walking and stair climbing times. Tendon rupture recurred as a result of falling and not restricting activity in two patients in the early weight group. The authors emphasized the importance of patient selection, being careful in the selection of patients for whom early weight-bearing protocol will be applied and recommend weight-bearing.\textsuperscript{[27]} In the light of the biomechanical findings obtained in the present study, it is important to conduct in vivo studies on the use of UHMWPE in Achilles tendon rupture surgery, although it is also dependent on the surgical technique.

The mtBU suture technique with UHMWPE suture use has possibly proven to be a reliable choice for tendon repairs, but as research is progressing, a new focus should be given toward research on the histopathologically evaluated tendon repairs in an in vivo setting.

A limitation of this study is that this data is only an indication of the performance of an appliance and cannot be linked to clinical improvements. The amount of reparable strength and the long-term effects of materials used in these devices have still not been determined. Any of these repair instruments could be clinically suitable and ultimately the choice of the surgeon should be based on clinical results.
Conclusions

The UHMWPE suture was significantly superior to the other sutures in terms of durability and strength. Moreover, this study, which was conducted to evaluate and compare the biomechanical features of mKE, mKR and mtBU suture techniques, conceptualizes the mtBU suture technique with the use of UHMWPE to be the most effective techniques in biomechanical terms.

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Conflict of Interest: None reported.

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   failure properties of all-suture anchors in human cadaveric shoulder greater tuberosities.

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Figure 1a-f: Preparation and measurements of the specimens (a-d), and views of biomechanical testing apparatuses (e-f).

a. Measurements of each specimen width, height, and length.

b. Marking the needle entrance point with 1 cm intervals, and determination of incision localization where is the mid-point of each specimen’s length respectively.

c. View of a sample specimen after suturation.

d. Measurement of each specimen regarding the width, height, length, and bulkiness of the repair area after the saturation techniques were applied.

e. View of a sample specimen applied to two custom-made clamps; one is fixed from the bony part with K-wires and other is fixed via bolt nuts.

f. View of fixed sample specimen to the biomechanical testing device.

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Figure 2a-c: Demonstrations of suturation techniques used in the study.

a. Modified tension Bunnell technique.

b. Modified Kessler technique.

c. Modified Krackow technique.
Figure 3a-f: Comparison of each suturation techniques in terms of each suture materials’ ultimate strength (a-c), and comparison of each suture materials’ in terms of each suturation techniques ultimate strength (d-f)

a. Modified Kessler suturation technique versus each suture materials.

b. Modified Krackow suturation technique versus each suture materials.

c. Modified tension Bunnell suturation technique versus each suture materials.

d. Polypropylene suture material versus each suturation techniques.

e. Polyester suture material versus each suturation techniques.

f. UHMWPE suture material versus each suturation techniques.
Figure 4a-f: Force (N) / Strain (mm) graphs of each suturation techniques versus suture materials and suture materials versus each suturation techniques.

a. Modified Kessler suturation technique versus each suture materials.

b. Modified Krackow suturation technique versus each suture materials.

c. Modified tension Bunnell suturation technique versus each suture materials.

d. Polypropylene suture material versus each suturation techniques.

e. Polyester suture material versus each suturation techniques.

f. UHMWPE suture material versus each suturation techniques.
Table 1. Characteristics of the specimens according to dimensions and biomechanical parameters of each saturation techniques groups

<table>
<thead>
<tr>
<th></th>
<th>Modified Kessler Technique n= 21</th>
<th>Modified Krackow Technique n= 21</th>
<th>Modified Tension Bunnell Technique n= 21</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Polypropylene n= 7</td>
<td>Polyester n= 7</td>
<td>UHMPE n= 7</td>
<td>Polypropylene n= 7</td>
</tr>
<tr>
<td>Length (mm, mean ± SD)</td>
<td>154.3 ± 11.4</td>
<td>149.3 ± 10.3</td>
<td>153 ± 15.4</td>
<td>148.4 ± 13.3</td>
</tr>
<tr>
<td></td>
<td>Distal Normal Tendon</td>
<td>9.4 ± 2.7</td>
<td>9.1 ± 3.1</td>
<td>8.2 ± 1.6</td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------------------</td>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>Cros-sectional Area Ratio Increase (% mean ± SD)</td>
<td>Repaired vs. Proximal</td>
<td>34 ± 18</td>
<td>32 ± 19</td>
<td>34 ± 11</td>
</tr>
<tr>
<td></td>
<td>Repaired vs. Distal</td>
<td>16 ± 12</td>
<td>16 ± 10</td>
<td>18 ± 7</td>
</tr>
<tr>
<td>Ultimate Strength (N, mean ± SD)</td>
<td>98.5 ± 5.7</td>
<td>112.3 ± 6.2</td>
<td>134.6 ± 11.2</td>
<td>78.3 ± 14.7</td>
</tr>
<tr>
<td>Strength Ratio (% mean ± SD)</td>
<td>18 ± 7</td>
<td>22 ± 11</td>
<td>15 ± 3</td>
<td>37 ± 11</td>
</tr>
<tr>
<td>Strength to 5 mm gap (N, mean ± SD)</td>
<td>33.1 ± 3.4</td>
<td>26.6 ± 9.4</td>
<td>38.7 ± 13.7</td>
<td>23.1 ± 8.3</td>
</tr>
<tr>
<td>Young’s Modulus (Kpascal, mean ± SD)</td>
<td>136/b.3 ± 287.2</td>
<td>125 b.7 ± 233.7</td>
<td>1563.5 ± 278.7</td>
<td>142.7 ± 376.8</td>
</tr>
</tbody>
</table>

Abreviations: SD: Standard deviation, UHMWPE: Ultra-high molecular weight polyethylene Cross-sectional Area Ratio = (((repaired cross-sectional area x 100) / normal cross-sectional area) - 100) Strength Ratio = (((peak failure force on repaired site x 100) / normal site).
*Statistically significant difference between the groups, Anova; a: .003
*bStatistically significant difference with both modified Kessler and modified Krachow with UHMWPE suture usage group.  
cStatistically significant difference within modified Kessler with polyester against UHMWPE suture usage group.  
dStatistically significant difference with both modified tension Bunnell and modified Krachow with UHMWPE suture usage group.  
eStatistically significant difference with both modified Kessler and modified Krachow with UHMWPE suture usage group.
Table 2: Failure modes distribution of suture materials in each suturation technique groups

<table>
<thead>
<tr>
<th></th>
<th>Modified Kessler Technique n= 21</th>
<th>Modified Krackow Technique n= 21</th>
<th>Modified Tension Bunnell Technique n= 21</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Polypropylene n= 7</td>
<td>Polyester n= 7</td>
<td>UHM WPE n= 7</td>
</tr>
<tr>
<td>Suture Rupture</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Knot Failure</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Gap Formation</td>
<td>1</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Suture pull-out from distal</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Suture pull-out from proximal</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Abbreviation: UHMWPE: Ultra-high molecular weight polyethylene
Table 3: Comparison of suture materials according to biomechanical parameters regarding each surgical technique.

<table>
<thead>
<tr>
<th></th>
<th>Polypropylene (n=21)</th>
<th>Polyester (n=21)</th>
<th>UHMWPE (n=21)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultimate Stren.</td>
<td>98.5 ± 5.7</td>
<td>78.3 ± 14.7</td>
<td>103.7 ± 21.7</td>
<td>112.3 ± 6.2b</td>
</tr>
<tr>
<td>(N, mean ± SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength to 5 mm</td>
<td>33.1 ± 3.4</td>
<td>23.1 ± 8.3</td>
<td>29.7 ± 9.4</td>
<td>26.6 ± 9.4</td>
</tr>
<tr>
<td>gap (N, mean ±  SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Young’s Modulus</td>
<td>1367.8 ± 287.2</td>
<td>1476.3 ± 376.8</td>
<td>1356.2 ± 295.4</td>
<td>1256.7 ± 233.7</td>
</tr>
<tr>
<td>(KPa, mean ± SD)</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Abbreviations: SD: Standard deviation, UHMWPE: Ultra-high molecular weight polyethylene

*aStatistically significant difference with both modified Kessler and modified Krachow with UHMWPE suture usage group. bStatistically significant difference within modified Kessler with polyester against UHMWPE suture usage group.
\[*\text{Statistically significant difference with both modified tension Bunnell and Krachow with UHMWPE suture usage group.} \]
\[\text{Statistically significant difference with both modified Kessler and modified Krachow with UHMWPE suture usage group.} \]

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