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Tibiofemoral contact pressures in radial tears of the meniscus treated with all-inside repair, inside-out repair and partial meniscectomy

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ABSTRACT

Background: To test contact pressures in the knee after treatment of a radial meniscus tear with an all-inside meniscal repair technique and compare the results with inside-out repair and partial meniscectomy.

Methods: Six non-paired cadaveric knees were analyzed with intra-compartment pressures measured at loads of 250 N, 500 N and 1000 N at 0°, eight degrees, 15°, and 30° of knee flexion. Compartmental contact pressures were measured for the intact medial meniscus, radial tear in the posterior horn, all-inside repair using the NovoStitch suture passer device (Ceterix Orthopaedics Inc., Menlo Park, CA), inside-out repair method, and partial meniscectomy. One-way ANOVA was used for statistical analysis.

Results: The greatest differences in peak pressures between treatments were observed under 1000 N load at 30° flexion (0.8 ± (SD) 0.1 MPa (intact meniscus), 0.8 ± (SD) 0.1 MPa (all-inside), 0.9 ± (SD) 0.1 MPa (inside-out) and 1.6 ± (SD) 0.2 MPa (partial meniscectomy)). Treatment with partial meniscectomy resulted in the highest peak pressures compared to all other states ($p < 0.0001$ at each angle). Repair of the radial tear using the all-inside technique as well as the inside-out technique resulted in significantly decreased compartment pressures compared to partial meniscectomies ($p < 0.0001$ at each angle). There were no significant differences between peak pressures in the intact state and after repair with the all-inside or inside-out techniques.

Conclusion: An all-inside repair technique using the NovoStitch suture passer can decrease contact pressures for a radial meniscus tear similarly to the inside-out repair technique when compared to partial meniscectomy.

Clinical relevance: This novel arthroscopic suture passer warrants further analysis in the clinical setting as it may be a reliable method for repair of radial meniscal tears through an arthroscopic all-inside technique.

1. Introduction

The meniscus is critical to reducing compartmental pressures in the knee by increasing contact area and decreasing contact pressures [1]. Previous studies have shown the detrimental effects of meniscal tears and meniscectomies on the articular surface of the knee [2–7]. Further, radial meniscal tears have been shown to affect the circumferential integrity of the meniscus and diminish its ability to absorb hoop stresses [8–13]. In particular, radial tears near the posterior horn of the medial meniscus can significantly compromise this circumferential stability similar to a subtotal meniscectomy [12,13]. The increased tibiofemoral contact pressures can then lead to rapid progressive degeneration of the compartment [5,6,14]. Therefore, effective treatment of these tears is needed to minimize utilization of meniscectomies and preserve joint integrity.

Currently, the gold-standard treatment for repairable meniscus tears is the inside-out arthroscopically-assisted suture technique [15–18]. This technique can cause complications, such as nerve injury, vascular injury, and wound infection [19–21]. Additionally, this technique usually requires a skilled assistant and the risk of needle stick injury is high, especially if attempting a repair in the medial compartment [19–21]. All-inside devices and techniques, such as the FasT-Fix and Meniscal-Dart, have been introduced for meniscal repairs with varying outcomes compared to the inside-out technique [22–24]. A limited number of studies including a systematic review comparing all-inside to the inside-out meniscal repair techniques have demonstrated comparable results when treating bucket-handle type tears [25]. However, there are only limited studies describing repair for radial meniscal tears [17,18] with no previous studies analyzing an all-inside repair technique.

The purpose of this study was to analyze the compartmental contact pressures after an all-inside repair of a radial tear in the posterior horn of the medial meniscus using a novel low profile suture passing device. The effects of this repair technique on tibiofemoral contact pressures was evaluated and compared to treatment with the inside-out repair technique and partial meniscectomy as well as the meniscus in the intact and torn states. We hypothesized that an all-inside repair would

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decrease tibiofemoral contact pressures similar to an inside-out repair when compared to partial meniscectomy.

2. Methods

Six fresh-frozen cadaveric knees with minimal degenerative changes, without meniscal or ligamentous injury, were chosen for this study. Based on previous studies analyzing contact pressures in the knee after radial meniscus tears [12], we performed an a priori analysis and determined that a sample size of six knees would be expected to detect significant differences of 1.3 MPa between meniscus states. Skin, subcutaneous fat and muscle were removed but the cruciate and collateral ligaments were left intact. The femur and the tibia and fibula were transected approximately 15 cm above and below the joint line and potted for biomechanical testing. Each knee was prepared in the same fashion and the five testing conditions (intact meniscus, radial tear, inside-out repair, all-inside repair and partial meniscectomy) were performed on each knee. The testing of all states for each knee was performed in a single setting to mitigate any effects of multiple freeze–thaw cycles on the tissue.

Piezoelectric contact pressure sensors (Tekscan 6900 sensors, South Boston, MA) were calibrated using two different loads before each use. They were covered in two layers of Tegaderm (3M, Minneapolis, MN) to protect from liquid ingress and allow for suture fixation. An osteotomy of the medial epicondyle [12–14] was made for access to the medial compartment before the Tekscan sensors were inserted submeniscally in the posterior horn and anchored via sutures to outer capsule tissue. The Tekscan was placed in the optimal orientation to fully capture contact forces within the compartment. The osteotomy was then reduced using 4.5 mm cancellous screws.

The femur and tibia were potted in SmoothCast polyurethane (Smooth-On, Easton, PN) and mounted into an MTS machine (Eden Prairie, MN) equipped with a calibrated 2.5 kN load cell. An axial compressive load of 250 N, 500 N and 1000 N was applied to the tibial end while the knee was flexed at 0, eight, 15, or 30° to replicate peak loading in the gait cycle [10,13,14]. A snapshot of the resulting tibial contact pressure was taken at each flexion angle for the intact meniscus, meniscus with a radial tear (approximately 75% of the width of the meniscus), torn meniscus repaired via two inside-out 2-0 Ethibond sutures, torn meniscus repaired via two 2-0 Fiberwire sutures placed with the NovoStitch arthroscopic suture passer (Ceterix Orthopaedics, Menlo Park, California), and partially meniscectomized meniscus (Fig. 1A–D). The NovoStitch device is an arthroscopic suture passing device that can shuttle sutures through the meniscus and retrieve the suture within the device. The suture is then brought out through the working portal of the knee and then tied and passed with a knot pusher (Fig. 2). The order of the different repairs was randomized so that half of the samples had all-inside performed first and the other half had inside-out performed first. Partial mensicectomy was performed last for all samples. Fiberwire suture-scissors were used to remove the previous repair carefully without damaging meniscal tissue when transitioning between repair methods.

Peak pressure, average pressure, and change in pressure across the tear were reported for each condition. The set-up and mounting on the MTS was regulated for each specimen as mounting jigs were marked to maintain consistent sagittal and coronal alignment (Fig. 3). A goniometer was also used to verify knee flexion angle with reported flexion on the mounting jig. Force in exerted in an axial load through the tibial shaft with the femur mounted in place at each measured angle. For each specimen, peak pressures were normalized to the torn state to account for individual variations in anatomy and width of tear. Finally, one-way ANOVA was used for statistical analysis.

3. Results

The mean age of the six non-paired cadaveric specimens was 64 years, with a range of 63 to 65 years, consisting of three females and three males, and three right and three left knees.

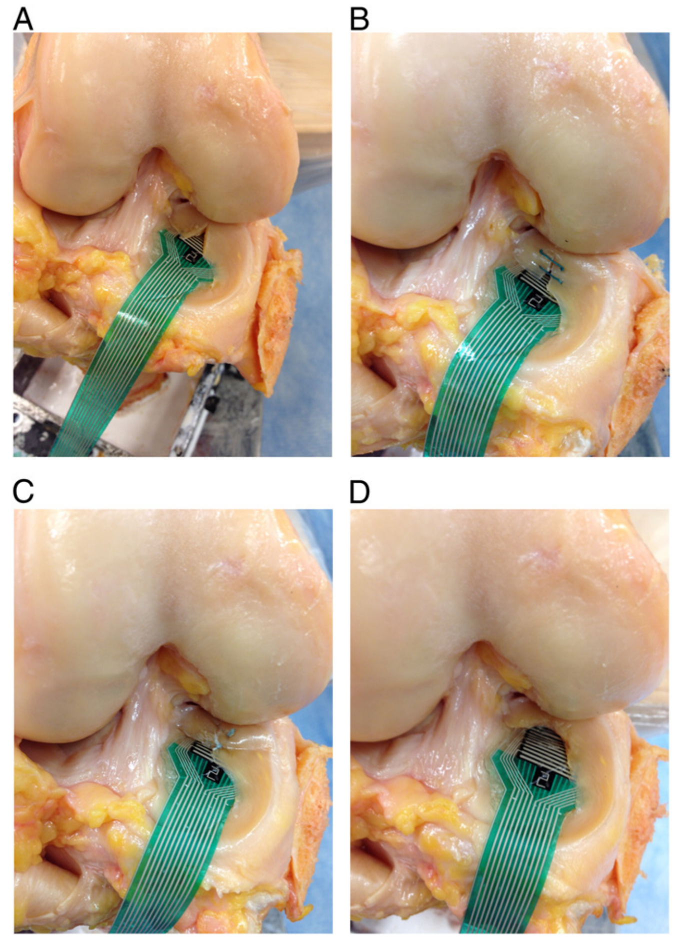

Fig. 1. A — Radial tear created in posterior horn of medial meniscus. The tear was created to be approximately 75% of the width of the meniscus. B — Inside-out repair with 2-0 Ethibond sutures. Two sutures were placed in a horizontal mattress configuration and in a classic inside-out fashion with knots tied outside of the capsule. C — NovoStitch suture passer all-inside repair with 2-0 Fiberwire sutures. Two sutures were placed in a horizontal mattress configuration using the NovoStitch suture passer and half-hitch knots were tied on the superior surface of the meniscus with the aid of a knot pusher from Ceterix Orthopaedics Inc. D — Partial meniscectomy to the level of the radial tear.

Average peak contact pressures across all angles with loads at 1000 N were 2.7 ± (SD) 0.3 MPa (intact meniscus), 4.5 ± (SD) 1.4 MPa (radial tear), 3.4 ± (SD) 0.8 MPa (NovoStitch), 3.6 ± (SD) 0.9 MPa (inside-out) and 5.9 ± (SD) 1.8 MPa (partial meniscectomy). Peak compartment pressures normalized to the torn state across all angles at 1000 N were 0.9 ± (SD) 0.1 MPa (intact meniscus), 1.0 ± (SD) 0.0 MPa (radial tear), 0.85 ± (SD) 0.04 MPa (NovoStitch), 0.9 ± (SD) 0.05 MPa (inside-out) and 1.45 ± (SD) 0.2 MPa (partial meniscectomy). A summary of normalized average pressure, peak pressure and force in the medial compartment of the knee at 1000 N for treatment of radial medial meniscus tears is presented in Table 1. Measurements are shown for flexion angles 0°, eight degrees, 15°, 30° as well as averaged across all angles. Measurements at 500 N and 250 N were proportional to results at 1000 N. For each angle, treatment with partial meniscectomy resulted in significantly higher average pressure, peak pressure and force compared to treatment with all-inside repair or inside-out repair ($p < 0.0001$).

Fig. 4 represents Tekscan pressure maps of peak compartment pressures between the intact meniscus, meniscus with a radial tear, and three different treatment methods at increasing knee flexion. Fig. 5 further illustrates the peak pressure values of these five states at different angles. At each flexion angle, treatment with partial meniscectomy resulted in the highest peak pressures compared to all other states. The greatest differences in normalized peak pressures between treatments were observed under 1000 N load at 30° flexion (0.8 ± (SD) 0.1 MPa (NovoStitch), 0.9 ± (SD) 0.1 MPa (inside-out) and 1.6 ± (SD) 0.2 MPa (partial meniscectomy)). Peak pressures between the intact and radial tear state approached significance ($p = 0.07$) similar to comparison of the tear state with repair with all-inside or inside-out technique. Finally, there was no significant difference between repair with the all-inside and inside-out techniques ($p = 0.67$).

4. Discussion

Our results show that the all-inside repair technique using the novel NovoStitch suture passer can decrease intra-compartmental pressures