INTRODUCTION:

Treatment of joint injuries is often fraught with post-traumatic loss of joint motion, or contractures. Studies on human joint contractures used tissues obtained late in the contracture process. An animal model is required for studies on the early processes leading to, and potential treatment of, post-traumatic joint contractures. The objective is to develop a rabbit knee model of permanent post-traumatic joint contractures to mimic the human condition. The hypothesis is that injury to the femoral condyles combined with immobilization of a rabbit knee joint will cause a lasting loss of motion when compared to the unoperated knee.

METHODOLOGY:

Nine skeletally mature (12 - 15 months old, 5.7 ± 0.5 kg) New Zealand White (NZW) female rabbits had the following operative intervention after approval by the institutional animal care committee. Under general anesthesia, an incision was made over the right thigh laterally, through which arthrotonomies were performed. Five-mm-squares of cortical bone were removed from the nonarticular portions of both femoral condyles, simulating a stable intraarticular fracture. An extraarticular 1.6-mm-diameter Kirschner wire (K-wire) was drilled through the tibia, passed posterior to the knee joint, and bent around the femur (Zimmer, Mississauga, ON). The knee was flexed around 150º. The incisions were closed withEthicon, Johnson & Johnson, Peterborough, ON). The left knee served as an unoperated control. The rabbits were allowed cage activity (0.1m³) following the operation. A second operation was performed to remove the K-wire.

The rabbits were immobilized for 5 - 10 weeks, had an examination under anesthesia (EUA) 5 - 6 weeks after the K-wires were removed and were sacrificed 10 -12 weeks after the K-wires were removed (15 - 20 weeks after the original operation). Clinically estimated knee joint range of motions, using a hand-held goniometer, were corrected under anesthesia and at the time of sacrifice. The hind limbs were dissected for biomechanical testing, leaving all soft-tissue intact from just above the patella to 1 cm below the end of the tibial tubercle, thus preserving the posterior joint capsule (Figure 1).

A mechanical goniometer allowing 4-degrees-of-freedom was used to measure in-situ joint angles (Figure 1). The knee joint was mounted with the MCL up and the axis of knee rotation centered over the pinion axis of the goniometer (Figure 1). The knee was mounted at a flexion angle of 90º and then extended maximally with an applied torque of 0.2 Nm using an MTS Testar II material testing system.

Statistical analysis was performed with a paired t-test. Significance was set at p < 0.05. Data are presented as mean ± standard deviation.

RESULTS:

Clinical examination estimating knee joint angles with goniometers found 90º flexion contractures at the time of pin removal (5 - 10 weeks immobilization) which decreased to 45º under general anesthesia 5 - 6 weeks after pin removal and remained around 45º at sacrifice 10 - 12 weeks after pin removal. The clinically estimated knee joint angles of the unoperated knee were 0º at all time periods. Biomechanical measures of the isolated experimental (right) knee joints at the time of sacrifice showed an average knee joint angle of 35 ± 9º and compared to 11 ± 7º for the unoperated left knee (Figure 2). The group means of the experimental and contralateral control knees were significantly different (p < 0.05).

DISCUSSION:

The combination of a stable intraarticular fracture with bone marrow bleeding into the joint and immobilization of the knee joint with an extraarticular pin completely within the limb produces a joint contracture in a rabbit knee 10 - 12 weeks after K-wire removal. Other authors have created knee joint contractures in rats or rabbits by immobilizing uninjured knees. However, uninjured rabbit knee joints immobilized 9 weeks regained full range of motion during biomechanical measures 9 weeks after the immobilization was discontinued. With our model of post-traumatic joint contracture, loss of joint motion was evident even after the joint was mobilized 1 - 2 times longer (10 - 12 weeks) than it was immobilized (5 - 10 weeks). From the serial clinical goniometer measures, the loss of joint motion decreased in the first interval of mobilization (5 - 6 weeks), but changed very little or not at all at subsequent time periods. This finding would suggest that these long lasting joint contractures may be permanent, similar to the permanent contracture that can effect human joints following trauma.

Placing a K-wire to immobilize the joint may not reflect the goal of perarticular fracture treatment allowing early joint motion. We tried the stable intraarticular fracture (cortical window removal from femoral condyles) without any immobilization in 6 rabbits, but contractures did not develop. This lack of contractures without immobilization led us to our current approach. There are human scenarios of wrist joint fractures treated with external immobilization across a joint for 6 - 8 weeks.

In summary, we have demonstrated that joint knee joints with a similar fracture pattern that were immobilized (5 - 10 weeks) developed a loss of knee joint extension measured 10 - 12 weeks after the joint was remobilized. Future work will include testing with the mechanical goniometer knees subjected to shorter and longer periods of mobilization following immobilization to determine if these long lasting contractures are permanent and when the changes become static. This model will be used for future studies on the mechanisms and treatment of post-traumatic joint contractures.

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