THE EFFECTS OF LIGAMENT REPAIR ON LAXITY AND CREEP BEHAVIOUR OF AN EARLY HEALING LIGAMENT SCAR

Introduction: One potential clinical problem in ligament healing is joint instability due to the progressive stretching of ligament scar during rehabilitation. To date, the majority of biomechanical studies on ligament scars have focused on scar mechanical strength. However, studies of ligament scar creep (or stretching) behaviour under low load cyclic stresses may have considerable clinical relevance.

Our purpose in this study was to test the effect of ligament repair on early scar laxity and creep resistance. Specifically we wanted to quantify early laxity, creep and creep recovery of injured ligament (MCL) scars after surgical repair. We propose that the resulting knee joint with ligaments and menisci intact was ready for rehabilitation.

Methods: Twelve skeletally mature female NZW rabbits (weighing 5.2±0.3 kg) were used. Five rabbits were used as normal controls. Seven rabbits had standardized bilateral injuries to their medial collateral ligament (MCLs). One MCL was cut in midsubstance and not repaired. The other had a sagittal Z-plasty as previously reported in detail [1]. Z-plasties were overlapped and repaired with 4-0 nylon sutures. The corners of the other cut MCL were simply marked with similar sutures for later identification. Six weeks after surgery, all rabbits were sacrificed. This interval of healing was chosen to simulate a period when we speculate that joints would begin to carry increased loads following an injury. The hind limbs were dissected so that the resulting knee joint with ligaments and menisci intact was ready for mechanical testing. Each joint was potted and mounted on a servohydraulic testing machine (MTS Systems, Minneapolis, MN, USA). After undergoing two cycles of 5N compression and 2N tension at 1 mm/min, the remaining tissues were dissected to isolate the MCL. The femur-MCL-tibia complex was then subjected to 2 cycles of 5N compression and 2N tension at 1 mm/min ending at 0.1 N to establish “ligament zero”. Cross-sectional area was measured in a custom built environment chamber (37°C, 95% humidity installed. “Ligament zero” was re-established in the test environment. The MCL was then loaded from “ligament zero” to a low physiologic load level (5% of normal failure capacity; 20 N) for cyclic creep (1 hour at 1 Hz), followed by one hour of creep recovery at zero load. After creep recovery, the MCL was subjected to failure at an extension rate of 20 mm/min.

MCL laxity was defined as the distance between “ligament zero” and the point where the tibial and femoral condyles began to transmit compressive load across the joint (0.1 N). Cyclic creep strain was defined as the strain at the peak of the 3600 cycle minus the strain at the peak of the first cycle. Creep recovery was determined over a one hour time period during which zero load was maintained, and was defined as the MCL strain at the beginning of the recovery period minus strain at the end of the recovery period. Strain was defined as the recorded deformation divided by the undeformed MCL length. Data were analyzed using t-tests with the Bonferroni correction assuming unequal variance (α=0.05).

Results: There was no significant difference in MCL laxity between repaired scars and normal controls. On the other hand, non-repaired scars were significantly more lax than both repaired Z-plasty scars and normal controls (Fig. 1). With regard to cyclic creep and creep recovery, there were no significant differences between non-repaired and repaired scars. Both creep significantly more and recovered significantly less than normal controls after an identical load history (Fig. 1, 2). There were no significant differences in the failure load, stiffness and tensile strength between gap scars and Z-plasty scars at this 6 week healing interval. As expected, all healing ligaments had significantly lower failure load, stiffness and tensile strength than normal controls.

Discussion: These results show that repair in this model (Z-plasty) does alter early ligament laxity demonstrating some positive effect. Interestingly however, repair did not alter early ligament creep behaviour. There were no significant differences in cyclic creep and irrecoverable creep between repaired and non-repaired ligaments. Whether the torn ligament was repaired or not, a healing ligament at six weeks post injury crept 3-4 times that of a normal ligament suggesting that such stretching may be possible in any repetitively loaded healing ligament.

Assuming that we can extrapolate from this model, the relevance of these observations is that acute ligament repair apparently does not alter the potential of the healing complex to creep; and that possible creep is still very high at 6 weeks of healing relative to normal ligaments. The creep of scar in repaired and non-repaired ligaments is 280% and 300% of a normal ligament, respectively. In other words, keeping loads low on a healing collateral ligament for up to six weeks appears to be important potentially to minimize its “stretching out.” Further, the results suggest that any condition which increases the load history of this healing ligament could, conversely, induce its stretching out.

The strengths of this study are that this model of healing in a young adult animal is likely the “best case scenario” of ligament healing, allowing immediate, anatomic repair in a reproducible model as compared with a similar injury in the opposite leg. Further, all loads were similar on both legs, both in vivo and in vitro. Thus comparisons are likely valid, and allow us to conclude that acute ligament Z-plasty repair is effective in decreasing short-term laxity of a healing MCL, but not effective in reducing the creep behaviour of these healing ligament scars. These six week scars would be prone to abnormal creep if loaded excessively.

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Figure 1. MCL Laxity, Cyclic and Irrecoverable creep strain in normal control, gap scar and Z-plasty scar.

Figure 2. Mean values of cyclic creep strain during 3600 cycles in normal control, gap scar and Z-plasty scar.