TIME DEPENDENT RELAXATION OF SOFT TISSUE ELEMENTS ABOUT THE WRIST FOLLOWING EXTERNAL FIXATOR APPLICATION

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Introduction

Ligamentotaxis is the application of axial tension to reduce and hold distal radius fractures through the extrinsic ligaments of the wrist. Longitudinal, external traction applied with a wrist external fixation device may also utilize the principle of the ligamentotaxis. Kaempfe et al.\textsuperscript{1} has shown that as duration of distraction across the wrist joint increases, functional outcome is adversely affected. Documented complications of prolonged or excessive distraction across the wrist joint include, digital stiffness, nonunion, RSD, and decreased grip strength. It has been established that anatomic restoration of palmer tilt is not possible by distraction alone\textsuperscript{2}. The purpose of this study is to determine the time dependent dissipation of extrinsic wrist ligament tension following application of wrist external fixation with distraction. A change in tensioned wrist ligament strain could account for the loss of reduction of externally fixed unstable distal radius fractures and may contribute to subsequent wrist stiffness.

Methods and Materials

Twelve fresh frozen matched cadaveric forearm specimens were obtained, amputated above the elbow joint. The specimens were then thawed to room temperature in preparation for experimental testing. Eight specimens were female and four male. The mean age of the specimens were 73 years (age range 64-88 years old). Six fresh-frozen cadaveric specimens were thawed to room temperature and constituted the control group. The six matched specimens were also thawed to room temperature and constituted the study group. For both groups, the base of the long finger metacarpal was exposed in each specimen and a 3/16-inch Steinman pin was inserted from dorsal to palmer through the base. A traction bow was then secured over the pin. Next, a dorsal approach to the bony surface of the distal one-third of the radius was performed in each specimen, and a second 3/16-inch Steinman pin was inserted. A second traction bow was secured over this pin. Sequentially, each cadaveric forearm in the control group was placed in a Model 1101 Instron mechanical testing device via removable metal links. Twenty pounds of traction was then applied to each specimen, attempting to recreate the tension applied to the radiocarpal joint following the application of wrist external fixation with maximum distraction. Using a 100 lb load cell, the following parameters were used for testing: cruise head speed 2 in/min, hold duration 1440 minutes, sampling rate of 5 pts/sec, and a 100 lb load cell. The change in tension in each cadaver forearm over a twenty-four hour period was determined by observing the tension decay readings on the Instron.

In the remaining 6 specimens, a dorsally based 1 cm wedge of bone was removed 2.5 cm from the radiocarpal joint, simulating an extra-articular distal radius fracture. To accomplish this, a limited posterior approach to the distal radius was made. Using an osteotome, the osteotomy was performed perpendicular to the dorsal cortex with the distal margin of the osteotomy parallel to the radiocarpal joint and the proximal margin angulated 40° away from the radiocarpal joint, 1 cm proximal to the distal margin, meeting the first cut at the volar cortex. The dorsally based wedge of bone was then removed. The specimens were then secured into the Instron mechanical testing device and a constant tension of 20 lbs applied. A strain gauge was placed in the bone. Tension across the radiocarpal joint of study specimen was recorded by monitoring tension decay observe on the Instro.

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Discussion

Although external fixation devices are designed to create tension at the fracture site through the principle of ligamentotaxis, such tension can only be maintained within the capacity of the ligaments, tendons, muscle and other soft tissue structures to sustain applied load. Without sustainable tension in the wrist ligaments, the principle of ligamentotaxis alone is not reliable to achieve and maintain distal radius fracture reduction.

Wrist ligaments are composed of 90% type I collagen and 10% type II collagen. The extrinsic ligaments of the wrist are viscoelastic structures, offering biomechanical compliance to applied loads. In general, the extrinsic wrist ligaments are "stiffer" than the other soft tissue constraints about the wrist joint having ultimate stresses between from 20-125%\textsuperscript{11}. This viscoelastic nature of the wrist extrinsic ligaments allow "creep" as the ligaments accommodate to applied longitudinal loads.

Conclusions

The cadaveric specimens examined in this study displayed a soft tissue stress relaxation response to applied longitudinal tension loads. These specimens not only demonstrated marked soft tissue compliance but did so within the first few hours following a sustained, 20 lb applied load from an Instron mechanical testing device. The presence of a disrupted dorsal radial cortex or periosteum, as would be seen in an extra-articular distal radius fracture, had little effect on soft tissue tension decay. We conclude that extrinsic wrist ligament tension is difficult to maintain using wrist external fixation devices applied in a distraction mode. We recommend the use of the wrist external fixator as a neutralization device, holding reductions which has been achieved by other means such as closed reduction, open reduction with internal fixation, or percutaneous pin fixation.

References


Results

Two specimens of the control group were excluded due to failure to complete testing. The average loss of tension in the control arms and the osteotomized arms was 55% (11 lbs of tension) and 59% (11.8 lbs of tension) respectively over the 24-hour period. There was no statistically significant difference in the stress relaxation behavior between normal and osteotomized wrist ligaments. In 6/10 specimens, 50% of ultimate tension loss occurred within 180 minutes of application. The 50% of ultimate tension loss occurred at a faster rate in the fracture group than in the "control" group, but was not statistically significant. The data from one control specimen was not collected for the entire 24-hour period and was deleted from the study.