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Original article

Biomechanical evaluation of the modified lasso technique

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ABSTRACT

Background: The Terrible Triad of the elbow is a constellation of elbow dislocation, radial head fracture and coronoid process fracture. A common type of coronoid fracture documented with this triad is type II Regan-Morrey coronoid fractures. The preferred fixation method for this fracture type is the lasso technique, medial-lateral tunnel orientation being the traditional approach. Considering elbow anatomy, we saw an opportunity to potentially improve fixation by altering the suture lasso tunnel orientation to a proximal-distal orientation.

Hypothesis: Two tunnels in the proximal-distal direction would result in greater biomechanical stability as compared to the traditional lasso technique.

Material and methods: A type 2 Regan-Morrey fracture was created in 12 fresh frozen cadaveric elbows at 50% of the coronoid height using an oscillating saw. The humero-ulnar joint was placed in 0 degrees flexion then loaded at a rate of 10 mm/min to failure.

Results: The control technique (medio-lateral tunnels) showed failure load of 150 ± 81N that was not significantly different ($p = 0.825$) than the 134 ± 116N measured for the modified technique (distal-proximal tunnels). The portion of the load-displacement curve used to calculate stiffness was linear ($R\hat{2} = 0.94 \pm 0.04$) with determination coefficients that did not differ between the two groups ($p = 0.351$). For stiffness, we measured 17 ± 13N/mm and 14 ± 12 N/mm respectively for control and modified techniques that did not result in a significant difference ($p = 0.674$).

Conclusion: In this attempt to improve the shortcomings of the lasso technique, we found that changing from medio-lateral to proximal-distal drilling directions did not result in an appreciable biomechanical benefit.

Level of evidence: Basic science study; Biomechanics.

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1. Introduction

The Terrible Triad of the elbow is a constellation of elbow dislocation, radial head fracture, and coronoid process fracture [1]. Associated coronoid fractures are most commonly type II according to the Regan-Morrey classification system [2]. A type II coronoid fracture is characterized by a fracture of 10–50% of the coronoid process measuring from the tip of the coronoid to the base of the trochlear notch [3–5].

For fixation of type II coronoid fractures, suture lasso is one possible fixation option often used when the coronoid fracture lacks cortical bone for screw purchase [6]. Biomechanically inferior to plates and screws, suture lasso is prone to instability [7] and fragment sliding [8]. When Iannuzzi et al. compared screw fixation to lasso fixation of these fractures, they reported roughly a two-fold improvement in strength and stiffness with the screw[4]. To compensate for the lack of biomechanical stability Kumar et al. has augmented the lasso with screw and plates in 20% of cases [9] but this has only been recorded for supporting fragments 50% or more in height [2,4,6,9,10].

In current practice, medial-lateral tunnel orientation is often chosen if performing the lasso technique [6,11]. Considering the pyramidal shape of the process [6] and the high bone density of the diaphysis of the ulna [12,13] we saw the opportunity to increase the volume of cortical bone purchased by the sutures considering a rotation in the layout of the tunnels.

In the current study, we aimed to assess the biomechanical stability of a modified lasso technique with two tunnels drilled in the proximal-distal direction and compare it with the currently used medial-lateral disposition of the tunnels. We hypothesized that two tunnels in the proximal-distal direction would result in

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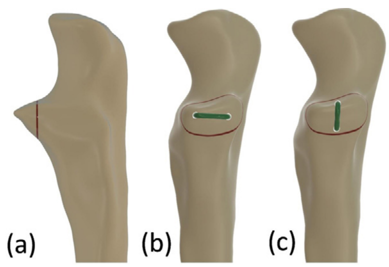

Fig. 1. Illustration of the recreated Regan-Morrey type 2 Regan-Morrey fracture (a), control group with tunnels drilled in the medial-lateral direction (b), and modified technique with tunnels drilled in the distal-proximal direction (c).

greater biomechanical stability as compared to the traditional lasso technique.

2. Material and methods

2.1. Specimen preparation

Following IRB approval at our institution, the biomechanical testing was performed on twelve fresh frozen cadaveric elbow joints (71 ± 16yo) of which 60% were from males. The specimens were thawed at room temperature (21 °C) 24 hours prior testing. Once defrosted each cadaveric specimen was sectioned at the mid-humerus level. A skin incision was made in the proximal-distal direction on anterior and posterior sides for the entirety of the specimen using a 22-blade scalpel (Bard-Parker, Caledonia, MI, USA). The skin was then removed exposing from the muscle and soft tissue structures below. The muscle, blood vessels, nerves, and other soft tissue structures were discarded to expose the bony structures of the humero-ulnar joint. The radius was transected 5 cm distal to the humero-ulnar joint using a hand saw and the head of the radius was removed from the specimen.

Two groups of equal size were created by randomizing left and right joints into the currently used lasso technique with tunnels drilled in the medial-lateral direction (control technique) and the modified technique with tunnels drilled in the distal-proximal direction (modified technique). Using a caliper to measure 50% distance between the trough of the trochlear notch and the tip of the coronoid process, we identified the location of our fracture line. In both techniques the holes were created perpendicular to the fracture line on the most anterior surface of the coronoid process using of a 2-mm drill bit (Stryker, Kalamazoo, MI, USA) at a distance of 1-cm apart (Fig. 1), this was confirmed using a vernier caliper (Shars, St. Charles, IL, USA). Following the tunnel preparation, we created a type II fracture using an oscillating saw (Stryker, Kalamazoo, MI, USA) to create the fragment. The coronoid fragment was then secured to the ulna using either the control or modified lasso technique. Using a suture passer (Medline, Northfield, IL, USA) #2 FiberWire suture (Arthrex, Karlsfeld, Germany) was threaded from anterior to posterior through the coronoid fragment, the coronoid footprint, and through to the posterior side of the ulna using the tunnels created previously. The suture was threaded to position the suture tails posteriorly on the ulna to be manually tensioned, then hand-tied in place. Humerus and ulna were fixed using an acrylic resin (Bondo, 3 M) in 3-in × 3-in aluminum boxes and further stabilized with two 0.25-in rods oriented in the medio-lateral direction.

2.2. Mechanical testing

The aluminum boxes hosting the bones were connected to the Instron model 8874 universal testing machine (Instron, Norwood, MA) through custom made fixtures. Following a previously used testing protocol for the elbow [14] the two bones were positioned to resemble a full extension of the elbow joint while the ulna was displaced against the joint at a rate of 10 mm/min (Fig. 2). The testing was performed until failure that consisted in at least the 80% load reduction from its peak. Data was acquired at a frequency of 100 Hz and for every 2N increments through the built-in software. Biomechanical performances were measured in terms of peak load and stiffness evaluated as the slope of the force-displacement curve measured from the beginning of the test to a first load reduction greater than 10%.

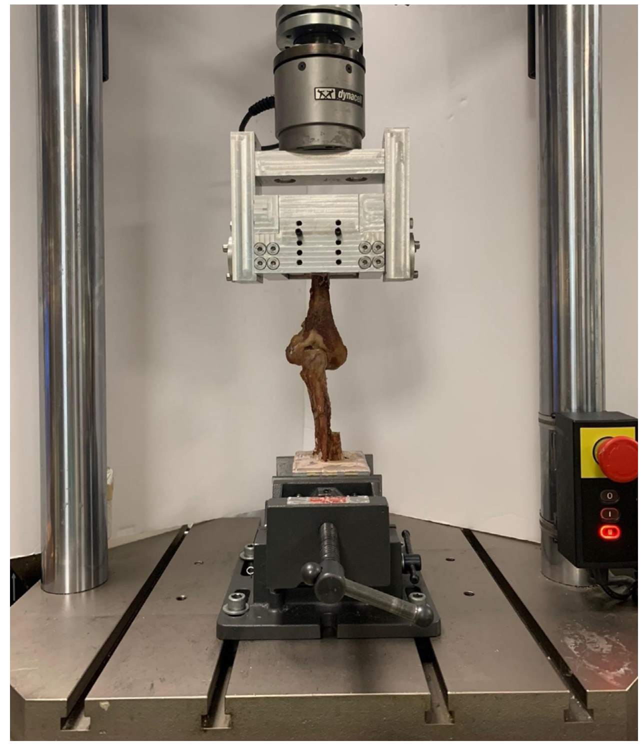

Fig. 2. Testing apparatus.

2.3. Ethical approval

The study has been performed on cadaveric specimens. The Institutional Review Board of Louisiana State University Health Sciences Center at Shreveport has determined that the current study was not research involving human subjects as defined by the DHHS and FDA regulations.

2.4. Statistics

The two variables measured for the two groups were compared using paired T-test at a level of significance of 0.05. The data was analyzed and plotted in Microsoft Excel (Microsoft, Redmond, WA, USA). A power of 80% calculated using the failure load of 207 ± 52N measured by Iannuzzi et al. for the analogous experiment here used for the control configuration and considering a 33% difference led to a sample size of nine specimens.

3. Results

The group characterized by tunnels drilled in the medial-lateral direction (control technique) have shown a failure load of 150 ± 81N that was not significantly different ($p = 0.825$) than the value of 134 ± 116N measured for the configuration with tunnels drilled along the distal-proximal direction (modified technique).

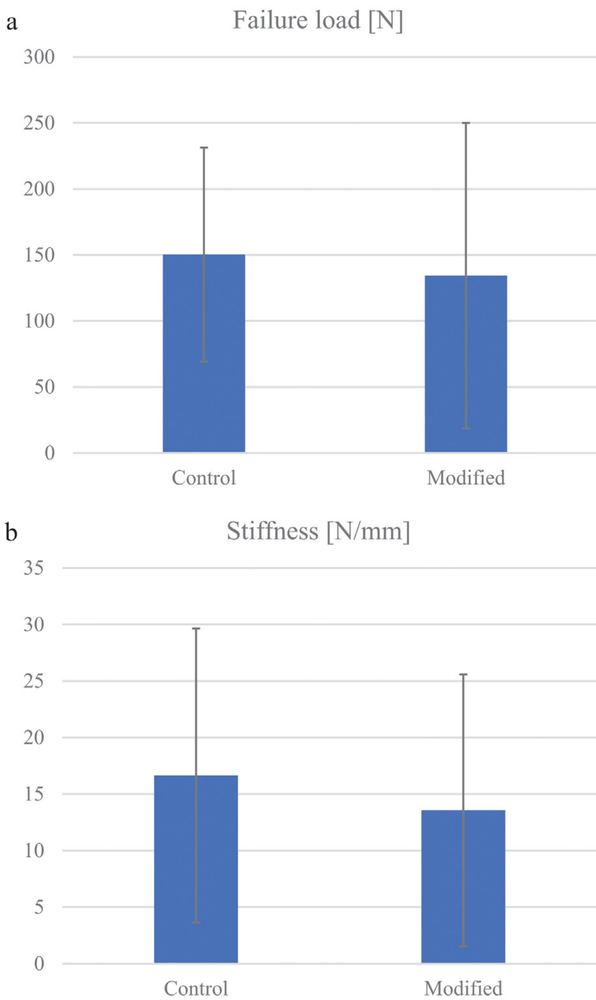

Fig. 3. Experimentally determined Failure loads (a) and Stiffnesses (b).

The portion of the load-displacement curve used to calculate the stiffness was linear ($R\hat{2} = 0.94 \pm 0.04$) with determination coefficients that did not differ between the two groups ($p = 0.351$). In terms of stiffness, we have measured values of 17 ± 13N/mm and 14 ± 12 N/mm respectively for the control and modified techniques that did not result in a significant difference ($p = 0.674$, see Fig. 3).

4. Discussion

Proper reduction and fixation of coronoid fractures improves elbow joint stability, [15,16]. Without stabilization of the humero-ulnar joint by the coronoid process, posterior translation of the ulna can occur [9,17–20] potentially injuring surrounding collateral ligaments and other soft tissue [6,9]. Reduction of the coronoid process helps restore the anterior capsule and has been show to enhance the stability of the humero-ulnar joint [21]. In the current study we modified the lasso technique drilling the tunnels in the proximal-distal direction. The modified technique resulted in a failure load of 134 ± 116N that is not significantly different from the load of 150 ± 81N measured for the medial-lateral ($p = 0.825$). The coronoid process is an insertion point for the anterior bundle of the medial ulnar collateral ligament (MUCL), anterior joint capsule, and the brachialis muscle [19,22]. MUCL inserts most distally of the three and defects are more associated with type 3 Regan-Morrey coronoid fractures [22]. But it has been documented that the anterior capsule inserts on the upper third of the coronoid [5,19,22–24]. Threading suture through medial-lateral tunnels to grab the horizontal aspect of the anterior capsule can be challenging requiring a large incision [8]. While the current study was purely designed to evaluate the biomechanical performance of the modified technique it must be noted that the use of proximal-distal tunnels would potentially allow for an easier grab through the anterior capsule before threading the suture back through the second tunnel. The orientation of suture tunnel fixation in type 2 coronoid fractures is clinically relevant because the unique shape of each fragment means that the placement of the tunnels can significantly impact the stability and strength of the fixation. Due to the curvature of the most distal side of the coronoid process, drilling tunnels in a proximal-distal orientation lines up the drill holes with the center of the fragment, promoting increased fixation stability [25]. Our findings suggest the orientation of the suture tunnels is irrelevant so surgeons can now focus on placing them through more robust bone therefore decreasing the risk of fracturing the fragment and increasing pullout strength. Suggesting that prioritizing the location of the tunnels based on bone quality rather than tunnel orientation within the fracture pattern can lead to more successful outcomes in surgical management. Furthermore, the modified lasso technique here proposed is aligned with the fibers of the brachialis muscle tendon, potentially reducing the potentials for lacerations that have been previously associated to the traditional lasso technique [7]. Because the coronoid has a triangular shape, the modified lasso technique allowed us to stay in the middle of the fractured bone which is thicker than the two medial and lateral sections used for the classic technique [26] and in this disposition, the suture sits on the bone with a larger contact area potentially reducing the applied contact pressure that for similar procedures has been associated to circulatory disturbance, and suture damage [27]. Apart from tunnel orientation, the modified lasso technique requires the same technical skills as the classic technique. Arguably, the learning curve is not as steep for the modified lasso technique due to the holes being in the thicker midline of the coronoid process compared to the thinner medial and lateral sides [12]. The alteration considered in this study affected only one step of the classic lasso technique, thereby maintaining the number of procedural steps, however quantification of all these aspects and OR time needs to be proven in future clinical studies. The modified technique can be performed with the same approach used for the lasso. Such approach is motivated by reduced risk for nerve, vessel, and tendon damage within the cubital fossa [28,29]. Arguably, a proximal-distal tunnel orientation would position the suture further from the brachial artery and median nerve compared to a medial-lateral tunnel orientation. The relative injury risk to the biceps brachii tendon is increased with the modified lasso technique but the overall absolute injury risk is much less when thinking of the potential damage to the neurovascular structures within the cubital fossa [30,31]. Not having found significant biomechanical differences, the modified technique can be considered an additional option. Differently from clinical practice, in this study, we decided to remove the ligamentous structures of the elbow joint as previously done by [4,14] to consistently recreate the bone fractures and focus strictly on the retaining function of the suture. The average load to failure we found for the classic technique was similar to Iannuzzi et al who reported 207 N (range 114–294 N) [4]. Whereas we compared the failure load of the classic lasso technique to a modified technique (134 ± 116 N) they compared it to screw fixation (405 N, range 204–581 N) [4]. Though screw fixation provides almost double the strength, there remains the fact that screw fixation can't be applied to type I and some type II Regan-Morrey fractures [11,20]. The main limitation of the study is determined by the number of specimens used for the testing, while the average values we have measured are comparable to the values previously measured for similar testing conditions [4] the variability in values that we have found is higher than the variability we have used to determine the number of specimens. However, we did not observe a trend toward a biomechanical advantage of the modified technique that would lead to a different conclusion with larger sample. The experience gained on executing the lasso on the exposed bone showed us that improvements toward the suture tightening could be crucial in improving the lasso technique. It has been documented that the effectiveness of suture knot increases with suture tightening [32]. This phenomenon is common also with procedures involving the shoulder [33–35], knee [36,37], and in biomechanical studies [38,39].

5. Conclusion

In conclusion, in this first attempt to improve the lasso technique, we have found that the change from medial-lateral to proximal-distal in drilling directions did not result in an appreciable biomechanical benefit. The technique here proposed, however, has the potential to give surgeons another option when it comes to securing type 2 Regan-Morrey coronoid fractures but collection of clinical evidence should be demanded to future studies.

Disclosure of interest

The authors declare that they have no competing interest.

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No funding has been received for the execution of this study.

Contributions

G.F.S., B.C. and R.S.B. have conceived the study and designed the experiments, S.R. and C.C. have acquired the data, S.R., K.P. and G.F.S have interpreted the data. S.R. and G.F.S. have drafted the work. All the authors have revised and approved the submission.

Artificial Intelligence Statement

No artificial intelligence was used for the writing of the submitted work.

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