A Biomechanical Consideration on Immediate Post Operative Mobilisation after Medial Ulnar Collateral Ligament Reconstruction

Qureish Vanat, Bin Wang, Minoo Esat, Mahmoud Chizari*

***Abstract*—The hypothesis examined in this study tests whether, the mechanical behavior of tendon grafts can determine if immediate post operative mobilization after medial ulnar collateral ligament reconstruction can occur. Cyclic loading, followed by single cycle loading was applied to sutured tendon grafts in suture-tendon and tendon-suture-tendon configurations using bovine tendon models. The result showed that the failure occurs at the tendon-suture interface, but the load required to cause failure is still higher than those that a patient would deliver postoperatively. It is therefore recommended to fully mobilize without restriction, achieving full range of motion early on and avoid the complications of elbow stiffness.**

***Index Terms*— early mobilization, medial ulnar collateral ligament, reconstruction, mechanical testing**

I. Introduction

Valgus instability of the elbow can cause pain, dysfunction and end the careers of professional sports men and women [1]. At risk are those over-head throwers, typically baseball players, javelin throwers and even football players. The pathology is thought to be chronic micro-trauma to the medial ulnar collateral ligament by repetitive ‘valgus overload’ of the elbow resulting in its degeneration and leading to complete failure and rupture of the ligament or laxity. Rupture or laxity cause abnormal kinematics at the elbow under valgus forces.

Abnormal kinematics result in the symptoms of instability and may lead to the end of a professional career and early on-set arthritis if not treated [1,2]. Repair of the ligament results in inferior outcomes and so different methods to reconstruct the ligament using tendon grafts have recently been employed [1,2].

Manuscript received February 05, 2011; revised April 05, 2011. All of the authors have no financial relationship to any private companies and organizations.

Qureish Vanat is with the Orthopaedic Department of St. Peters and Ashford Hospitals in London, UK

Bin Wang is with the Mechanical Engineering department in the School of Engineering and Design at Brunel University West London, UK

Minoo Esat is with the School of Engineering and Design at Brunel University West London, UK

Mahmoud Chizari is with Center of Orthopaedic Research at School of Engineering and Design, Brunel University West London, UK, (corresponding author: Mahmoud Chizari. Phone: +447886454320; e-mail: mahmoudchizari@yahoo.com).

Postoperative recovery after such an operation usually requires a degree of reduced motion and gradual mobilisation over a long period that often takes the patient to one year before reaching his or her pre-injury performance levels.

Postoperative regimes vary, but essentially require immobilization in a cast for at least one week allowing soft tissues to settle and for pain management, followed by a hinged brace on the elbow allowing a restricted range of motion in extension-flexion only. At 6 weeks full extension and flexion should have been reached and if not, corrected at this stage. Only at 12 weeks is the patient allowed to begin more vigorous strengthening exercises [3,4,5]. Valgus motion at the elbow joint would begin by 4 months post operation and included short throwing distances initially and only at close to 6 months before any degree of significant acceleration force is permitted. This would progress gradually over the next 6 months before attempting the very highest acceleration through the joint 290 N and 3000 deg/s [2,6].

Issues may arise due to the effect of this prolonged regime on postoperative rehabilitation. Classically the elbow undergoes extrinsic contracture resulting in stiffness and reduced range of motion in extension and flexion [7,8]. This may have consequences when returning to the very highest demands on the elbow at a professional level.

Classically the two main methods of reconstructing the medial ulnar collateral ligament are the modified Jobe technique and the Docking technique [1,10,11]. These two employ the use of a tendon graft harvested from autologous or an allograft sources. They also require bony channels in the distal humerus and proximal ulnar through which the tendon graft is weaved and ultimately the free ends are fixed together, this is a ‘Tendon-Suture-Tendon’ configuration Fig. 1.

This contrasts to the Docking technique where the bony channels are arranged in a triangular fashion to recreate the anterior bundle of the ulnar collateral ligament more closely. The anterior bundle is thought to provide the largest amount support against the extremes of valgus stress on the elbow joint compared to the posterior and transverse bundles [2]. The graft again is weaved through the channels, but has its free ends sutured with a whipstitch. This is a ‘Tendon-Suture’ configuration. The sutures are used to tension the graft in its position and tied together tightly over the bone.

Both techniques are widely used but recent publications show the superiority in outcome data for the Docking technique [1].

ISBN: 978-988-19251-5-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

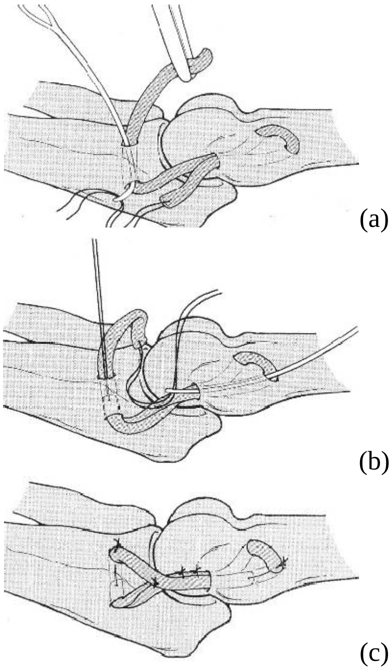

Fig. 1. Schematics of modified Jobe technique with pre-drilled bony channels. The tendon graft passes through the channel in a figure-of-eight fashion, ends overlapped giving the ‘Tendon-Suture-Tendon’confuguration [9].

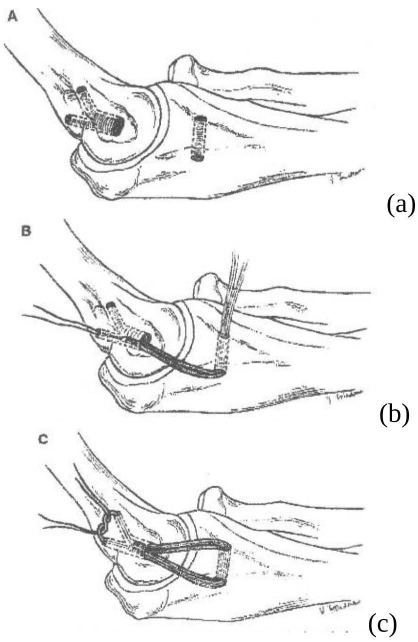

Fig. 2. Schematics of Docking technique. The bony channels are drilled in a triangular fashion (a); the tendon graft with the ends whip stitched is fed through the channels (b); the sutures ends are tensioned and tied together over the bony ridge (c), [1]. This involves the ‘Tendon-Suture’ configuration.

Aim of the study

1-To evaluate the mechanical parameters of the graft types used in both Jobe and Docking graft configuration models and obtains the load-displacement characteristics under cyclical and continuous loading.

2- To examine the mechanical behavior of the graft configurations and determine whether immediate post operative mobilization after medial ulnar collateral ligament reconstruction is possible.

II. MATERIAL AND METHODS

A. Testing suture and tendon specimens

Tests were performed separately on the suture alone, the tendon alone and finally on the two tendon suture configurations.

The sutures were cut into the same lengths. Each length had its end tied with 7 knots to make a loop. Ten loops of the Fibreloop suture were made. The length of each suture loop was 80 mm and the 7 knots approximated a length of 8 mm on each loop. The tail of the loop was cut to an approximate length of 20 mm.

The specimens were tested under single cycle uni-axial tensile loading with a rate of 50 mm/min.

To understand the material properties of the tendon alone, ten bovine digital flexor tendons were prepared and tested. Each tendon strand was prepared in the same way. The size of the specimens was 100 mm in length and 7 mm in diameter. Zigzag grippers were used to secure the tendon specimens in the testing machine. The free length (gauge length) of the specimen was 60 mm.

Single cycle load to failure test with a loading rate 50 mm/min was applied on the specimens to get load-displacement data.

B. Testing sutured tendon

To examine the Docking technique model, a test was performed to evaluate the mechanical behaviour of the sutured site of the tendon graft, in the ‘Tendon-Suture’ configuration. Single strand digital flexor tendons were used for testing the sutured junction. The tendons were cut and trimmed to a length of 80 mm and diameter of 7 mm. One end of the tendon specimens was sutured using whipstitch method for the length of 30 mm. This group was made up of 10 specimens whipstitched using a Fibreloop suture.

The prepared whipstitched tendon specimens, which described earlier, were hooked onto a rig from sutured side and the distal end of the tendon was secured in a special made zigzag gripper then mounted in the testing machine.

The specimens were loaded accordant to the previously proposed loading protocol for 100 cycles from 10 to 50 N followed by 100 cycles from 10 to 75 N at a rate of 0.5 Hz. The cyclic loading was followed with a single cycle load-to-failure test at a rate of 50 mm/min to test the specimens.

To evaluate the Jobe technique model, the same number of specimens was papered but the tendons were looped and the tendon ends were sutured with a length of 30 mm with the above mentioned suturing technique. The specimens then hooked and mounted in the testing machine and tested with above method.

ISBN: 978-988-19251-5-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

III. RESULTS

A. Mechanical properties of tendon

The tendon strands were clamped rigidly in the test rig (Instron 1026) and loaded at a loading rate of 50 mm/min. The data was recorded in the form of load-displacement. The mode of failure was determined visually.

The location of the failure in the tendon occurred in the vicinity of the zigzag griper. No snap failure occurred and the failure was due to breakage of tendon fibers. Fig. 3 shows the average load-displacement result of the tested samples. The maximum failure load of the tendon strands from average result was about 1200 N.

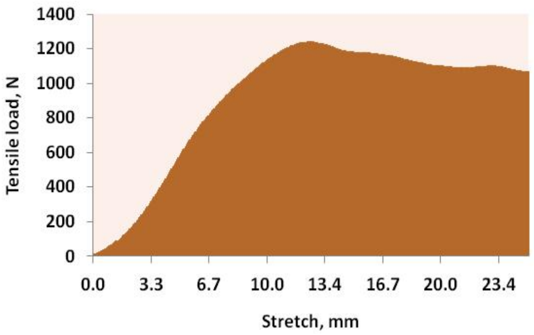

Fig. 3. Average load-displacement result of the tendon strand specimens under load to failure test

B. Mechanical properties of suture

The loop suture was clamped rigidly in the test rig and loaded at a loading rate of 50 mm/min. The mode of failure was determined visually.

The location of the failure in the suture occurred in the vicinity of the knot. Failure occurred as a sudden snap. Fig. 3 shows the average load-displacement result of the tested samples. The maximum failure load of the sutures which determined from average result was 320 N for Arthrex Fiberloop No 2.0 suture.

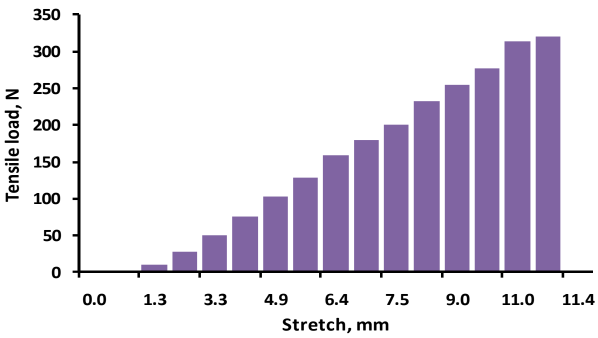

Fig. 4. Average load-displacement result of the looped sutures (Arthrex Fiberloop No 2.0) under load to failure examination.

C. Strength of sutured tendon junction in the tendon-suture configuration

The cyclic loading test followed by load-to-failure was performed on the specimens. While loading the specimens, the displacements and forces were recorded and slippage of the suture and deformation of the tendon in the sutured region were monitored. The mode of failure was also determined.

10 samples in were tested. The tendon showed immediate stretching and by increasing the load the suture cut into the tendon and eventually broke the tendon. The failure in the most specimens was due to a progressive breakage of the tendon fibers. The mechanism of failure was slippage of the suture at the first suture throw and tearing of the first knot through the most distal portion of the tendon. The time of suture rupture was identical with the time of maximum force. The force-displacement curve after that incident was sharply dropped to zero. The maximum failure loads (mean value) of the specimens was 311 N for Fiberloop sutured tendon grafts as shown in Fig. 5.

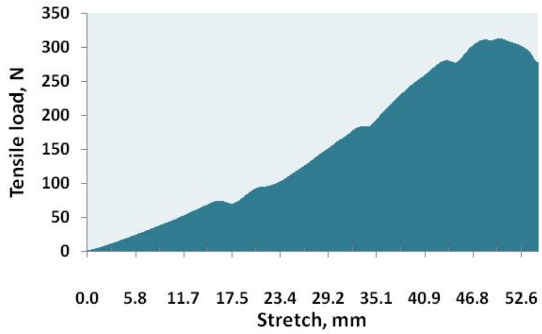

Fig. 5. Result of the sutured tendon grafts under a single cycle load to failure test.

D. Strength of sutured tendon junction in the tendon-suture-tendon configuration

The looped specimens were hooked onto the rig then mounted in the testing machine.

The cyclic loading test followed by load-to-failure was performed on the specimens. The mode of failure was also determined.

The mode of failure and slippage of the suture and deformation of the tendon ends on the loop were monitored.

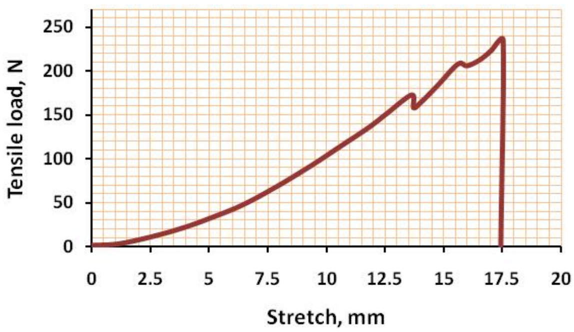

Fig. 6. Result of the tendon to tendon sutured grafts under a single cycle load to failure

10 samples in were tested. The tendon showed immediate stretching and by increasing the load the suture cut into the tendon and eventually broke the tendon from both tendon ends. The failure was due to a progressive breakage of the tendon fibers at both ends. The maximum failure loads (mean value) of the specimens was 356 N as shown in Fig. 6.

ISBN: 978-988-19251-5-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

IV. DISCUSSION

Postoperative rehabilitation can be modified to allow more aggressive mobilisation earlier by knowing the effect of these forces on the graft [12]. By mobilizing patients earlier could they achieve closer to perfect range of motion sooner, and reduce the time required to regain pre-injury muscle power. Thus preventing loss of function and achieving peak performance. Even small losses in range of motion can affect elite performance. Unfortunately many papers do not report the loss in range of motion [2].

Displacement of the tendon graft will occur over a period of time. Integration is said to occur in the bony channels and revascularization to the tendon substance, allowing the tendon to be a living structure.

This maybe a reason for prolonged rehabilitation, however this is not the basis on which the reconstruction works and there are no conclusive studies reporting the cellular biology of the tendons months or years after the procedure.

Studies have shown as in ACL reconstruction that degeneration occurs to the tendon over that period of time before it is tested in the rehabilitation phase, this usually occurs at about 3 weeks post graft insertion in anterior cruciate ligament reconstructions.

The gain from early mobilization is to allow the mobilization of muscle, its subsequent improvement in power and hence blood flow to healing tissue including revascularization of the grafted tendon which is the hope of all surgeons. Also strengthening the muscle surrounding the elbow joint would allow effective co-contraction further stabilizing the joint and reducing inadvertent valgus forces on the newly inserted tendon graft. This would also help to prevent permanent deformation of the tendon.

Previous studies have shown that the ultimate tensile load in extension-flexion and valgus forces on the joint are 290 N [2,6]. This study has shown that the failure load on both configurations used in the Jobe and Docking techniques are higher than 290N. These results suggest that achieving full range of motion would require less force and hence would not endanger the reconstruction.

V. CONCLUSIONS AND FUTURE WORKS

Assessment of the material properties of tendon and suture interface reasonably represents the material properties of the whole reconstructed graft used in the medial ulnar collateral ligament.

Postoperative rehabilitation can be expedited to allow more aggressive mobilization earlier.

REFERENCES

[1] G. A. Paletta, Jr, S. J. Klepps, G. S. Difelice, T. Allen, M. D. Brodt, M. E. Burns, M. J. Silva, R. W. Wright, Biomechanical Evaluation of 2 Techniques for Ulanar Collateral Ligament Reconstruction of the Elbow. The American Journal of Sports Medicine, 2006, vol. 34 no. 10, pp. 1599-1603.

[2] M. A. Vitale, C. S. Ahmad, The Outcome of Elbow Ulnar Collateral Ligament Reconstruction in Overhead Athletes. The American Journal of Sports Medicine, 2008, vol. 36 no. 6, pp. 1193-1205.

[3] M. R. Greiwe, B. B. Kroll, C. S. Ahmad, Medial Collateral Ligament Reconstruction. Operative Techniques in Orthopaedics, 2009, vol. 19, pp. 243-250.

[4] R. K. Rahman, et al. Elbow medial collateral ligament injuries. Current Review of Musculoskeletal Medicine, 2008, vol. 1, no. 3-4, pp. 197-204.

[5] J. T. Rohrbough, D. W. Altchek, J. Hyman, R. J. Williams, J. D. Botts, Medial Collateral Ligament Reconstruction of the Elbow using the Docking Technique. The American Journal of Sports Medicine, 2002, vol. 30 no. 4, pp. 541-548.

[6] C. C. Dodson, A. Thomas, J. S. Dines, S. J. Nho, R. J. Williams, D. W. Altchek, Medial Ulnar Collateral Ligament Reconstruction of the Elbow in Throwing Athletes. American Journal of Sports Medicine, 2006, vol. 34 no. 12, pp. 1926-1932.

[7] M. J. Park, H. G. Kim, J. Y. Lee, Surgical treatment of post-traumatic stiffness of the elbow. Journal of Bone and Joint Surgery British, 2004, vol. 86-B, issue 8, pp. 1158-1162.

[8] Y. G. Rhee, Cho N. S., C. T. lim, J. W. Yi, Debridement Arthroplasty for Post-traumatic Stiff Elbow: Intraoperative Factors Affecting the Clinical Results of Surgical Treatment. Clin Orthop Surg, 2009, vol. 1, no. 1, pp. 27-33.

[9] S. T. Canale, (Ed.) Cambell's Operative Orthopaedics, Mosby, 2003.

[10] J. E. Conway, F. W. Jobe, R. E. Glousman, M. Pink, Medial Instability at the Elbow in Throwing Athletes: Treatment by Repair or Reconstruction of the Ulnar Collateral Ligament. Journal of Bone and Joint Surgery American, 1992, vol. 74, issue 1, pp. 67-83.

[11] J. L. Koh, M. F. Schafer, G. Keuter, J. E. Hsu Ulnar Collateral Ligament Reconstruction in Elite Throwing Athletes. The Journal of Athroscopic and Related Surgery, 2006, vol. 22, issue 11, pp. 1187-1191.

[12] Q. Vanat, and M. Chizari, Is Immediate Mobilisation Possible After Medial Ulnar Collateral Reconstruction. Journal of Biomechanics, 2010, vol. 43, Sup. 1, pp. 44-45.

ISBN: 978-988-19251-5-2
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)