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by Erica

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Quantitative Analysis of Forearm Instability in an Essex-Lopresti Injury Model: Effects of Radial Head Replacement and IOM Reconstruction

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Abstract

Background:

Essex-Lopresti injuries, characterized by radial head fracture, interosseous membrane (IOM) rupture, and distal radioulnar joint (DRUJ) disruption, lead to forearm longitudinal instability, ulnar-positive variance, pain, and loss of rotation. While radial head replacement (RHR) is widely used, the biomechanical importance of IOM reconstruction remains debated. This study aimed to quantify the relationship between sequential forearm stabilizer disruption and longitudinal translation and rotation, and to assess the ability of RHR with IOM reconstruction to restore stability.

Methods:

Ten fresh-frozen cadaveric forearms underwent sequential sectioning of the proximal radioulnar joint (PRUJ), DRUJ, partial and complete IOM, and radial head, followed by anatomic, overstuffed, and understuffed RHR combined with IOM reconstruction. Rotational arc was measured using a custom jig and goniometer, and longitudinal displacement was measured under axial load using a materials testing machine. Statistical analysis included paired t-tests and repeated-measures ANOVA.

Results:

Sequential sectioning produced significant increases in rotational and longitudinal instability. The total forearm rotation arc increased from 84° (intact) to 171° (complete injury; $p<0.001$), with the greatest increase in supination. Longitudinal displacement increased by ~30% with PRUJ/DRUJ injury, 100% with partial IOM sectioning, 200% with complete IOM disruption, and 435% after radial head removal ($p<0.001$). RHR with IOM reconstruction restored rotation (90°; $p=0.518$ vs.

intact) and axial displacement (neutral, 4.37 mm; supination, 6.34 mm; p=1.000 vs. intact) to near-normal levels. Overstuffed RHR restricted rotation (66.8°, p=0.003), while understuffed RHR showed no significant difference from intact.

Conclusions:

Loss of forearm stabilizing structures results in both longitudinal translation and rotational instability. In the Essex-Lopresti injury model, forearm rotation and longitudinal translation increased approximately twofold and fourfold, respectively, compared to the intact forearm. Radial head replacement combined with interosseous membrane (IOM) reconstruction effectively restored both longitudinal and rotational stability to near-normal levels.

Introduction

The Essex-Lopresti lesion, characterized by a radial head fracture, interosseous membrane (IOM) disruption, and distal radioulnar joint (DRUJ) injury, results in a loss of longitudinal forearm stability.[1] Chronic Essex-Lopresti injuries can lead to ulnar-positive variance at the wrist, causing ulnocarpal impaction syndrome, chronic wrist pain, decreased forearm rotation, and diminished grip strength.[2-7]

Despite its clinical severity, the optimal management of Essex-Lopresti injuries remains a matter of debate. Essex-Lopresti originally emphasized the importance of early diagnosis and advocated for radial head replacement in cases of non-reconstructible fractures to maintain the anatomic relationship between the radius and ulna during IOM healing.[8] Prior biomechanical studies using sequential forearm sectioning models have highlighted the critical roles of the IOM, radial head, and DRUJ in preserving forearm stability..[9] However, these experimental models have typically not included radial head arthroplasty, limiting their translational relevance for guiding surgical treatment.

A key challenge in clinical practice is determining when IOM reconstruction is necessary. While often considered the central lesion in forearm instability, IOM reconstruction is technically demanding and its indications are not clearly defined. In contrast, radial head replacement is a more straightforward procedure and widely accepted in the management of these injuries. Currently, there is a lack of objective, quantitative data describing how sequential disruption of forearm stabilizers affects longitudinal and rotational stability, and how much stability can be restored by radial head arthroplasty with or without IOM reconstruction.

The objectives of this study were threefold: (1) to quantify the relationship between loss of forearm stabilizing structures and radioulnar longitudinal translation, (2) to assess the relationship between stabilizer loss and forearm rotational motion, and (3) to evaluate the role of radial head replacement and IOM reconstruction in restoring forearm stability. We hypothesized that (1) progressive disruption of forearm stabilizers would result in proportional increases in longitudinal translation and rotational motion, and (2) radial head replacement combined with IOM reconstruction would restore forearm stability to near-intact levels.

Materials and methods

Gross tissue preparation

Institutional review board approval was obtained prior to the study (approval numbers S2020-1463-0001/2020-0981). Ten fresh-frozen human upper extremities, amputated at the mid-humeral and radiocarpal levels, were used for this study. The mean donor age at death was 65.6 years (range, 64–68 years). Specimens were stored at −25°C and thawed overnight at room temperature before dissection.

To ensure that all specimens were free of gross abnormalities, the passive range of motion in flexion-extension and pronation-supination was assessed. The integrity of the collateral ligaments was confirmed by performing manual valgus and varus stress testing. Dissection was performed carefully by a fellowship-trained orthopedic surgeon specializing in upper extremity surgery (E.K.), following previously published protocols[9], with particular care to preserve the interosseous membrane (IOM) and the integrity of the proximal and distal radioulnar joints (PRUJ and DRUJ). Throughout specimen preparation and testing, the tissues were kept moist using continuous irrigation with normal saline.

Experimental set-up

Each forearm underwent two tests: rotational testing and translational (axial) loading, with a 30-minute resting period at room temperature between tests. The sequence of sequential sectioning was as follows: proximal radioulnar joint (PRUJ), distal radioulnar joint (DRUJ), partial interosseous membrane (IOM), complete IOM, and radial head resection **(Figure 1)**.

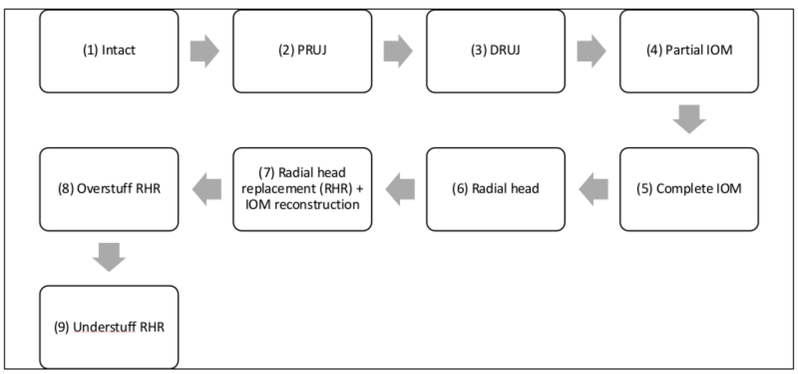


Figure 1. Sequence of forearm structure sectioning followed by radial head replacement (RHR).

Radial head replacement (RHR) was performed at the end of the sectioning sequence. Sectioning of the proximal radioulnar joint (PRUJ) was carried out using a vertical incision through the joint capsule and annular ligament (Figure 2)[10] (Figure 2) Sectioning of the distal radioulnar joint (DRUJ) was performed via a vertical incision through the triangular fibrocartilage complex (TFCC), distal radioulnar ligaments, and joint capsule.[9]

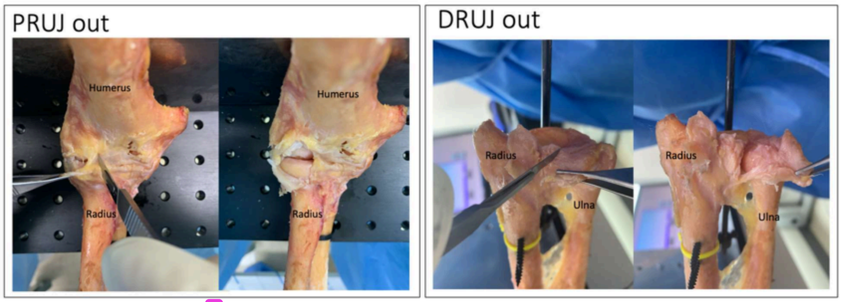


Figure 2. Sectioning of the proximal radioulnar joint (PRUJ) (left) and distal radioulnar joint (DRUJ) (right) in the specimen.

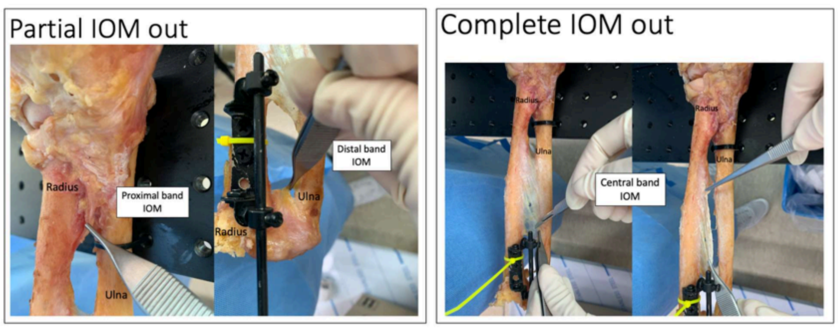


Figure 3. Sectioning of the proximal and distal bands (left) and the central band (right) of the interosseous membrane in the specimen.

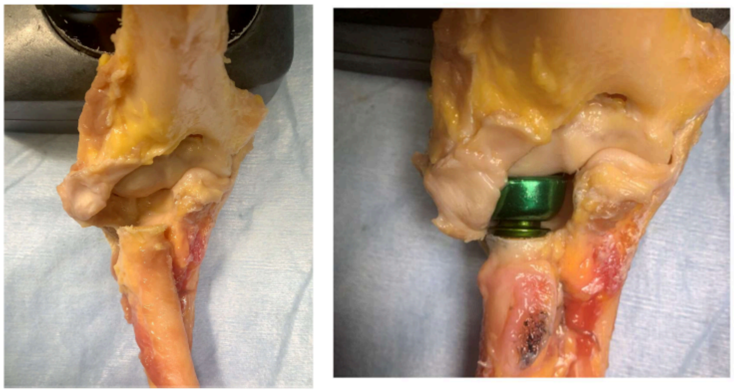


Figure 4. Radial head removal performed at the neck level (left), followed by radial head replacement (RHR) (right).

Partial sectioning of the interosseous membrane (IOM) involved cutting the proximal and distal bands, followed by sectioning of the central band to complete the IOM disruption (Figure 3)[1]. The radial head was resected at the neck using an oscillating saw to simulate the Essex-Lopresti injury model.

Following radial head removal, RHR and IOM reconstruction using a palmaris longus tendon graft were performed as previously described (Figure 4)[11]. The RHR procedure followed the manufacturer's guidelines. The anatomical radial head prosthesis used in this study was the Acumed Radial Head System Solutions 2 (Acumed, LLC, Oregon, USA). The native radial head diameter was measured using the Acumed ARH Solutions 2 Impactor Block, and implant size was selected according to the manufacturer's recommendations. The trial radial head and standard stem were inserted until the coronoid contacted the trochlea without radioulnar joint step-off.

To simulate implant malpositioning, the overstuffed RHR condition was created by increasing the implant height by 2 mm, and the understuffed RHR condition was created by decreasing the implant height by 2 mm (Figure 5).

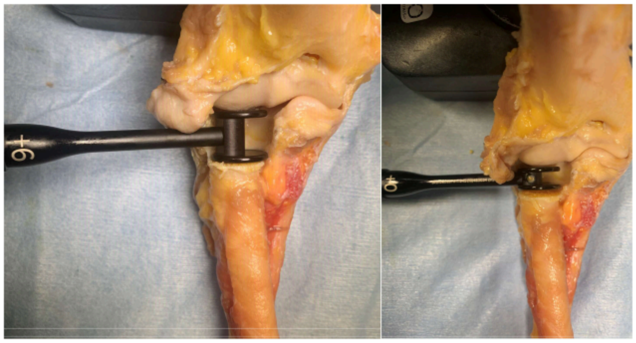


Figure 5. Overstuffed (left) and understuffed (right) RHR models, created according to the tested height gauge.

Rotational testing

For the rotational test, each specimen was mounted in a custom-made jig designed to securely hold the forearm while allowing controlled application of rotational motion (Figure 6)[12] An external fixator system was used to maintain the elbow at 90 degrees of flexion. A goniometer was positioned at the wrist level in the axial plane to measure changes in the rotational angle following each sectioning sequence. The speed of rotational movement was controlled using a customized servo-motor device.

To stabilize the forearm, the ulnar shaft was drilled and rigidly clamped to the fixed testing table to prevent any movement. The distal radius was drilled and secured to a metal bar connected to the servo-motor, enabling the radius to rotate relative to the ulna at a constant angular speed of 4.75 revolutions per minute (rpm). The axis of rotation was determined according to previously published methods.[13]

Figure 6. Rotational test setup showing each specimen mounted in a custom-made jig designed to securely hold the forearm while allowing controlled rotational motion.

Translational testing

For the translational loading test, each specimen was positioned in a uniaxial universal materials testing machine (Universal Testing Machine ST-1001; SALT, Daejeon, Korea), with the distal radius secured using a toothed clamp (Figure 7). The elbow was flexed to 90 degrees and rested on the base platform, which allowed testing in 40 degrees of pronation, neutral position, and 40 degrees of supination, adjusted using a protractor.[14]

A calibrated graph paper was placed in the background of the experimental setup as a reference for measuring translational displacement. A 37-mm prime lens digital camera was fixed in position for consistent image acquisition across all experiments.[15] The alignment of the graph paper and camera was checked and adjusted prior to each test.

A preload of 5 N was applied for 1 minute, followed by continuous axial compression up to 134 N at a displacement rate of 1 mm/s.[1, 16, 17] Radial displacement was measured at the end of each loading test.[18] (Figure 8). The output data from the testing system were exported as comma-separated values (.csv) files for analysis (Figure 8).

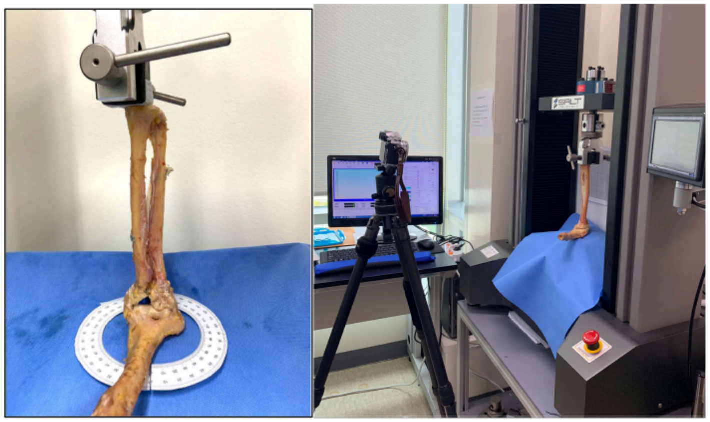


Figure 7. Longitudinal (translational) test setup showing the specimen positioned in the uniaxial testing machine (left), with image acquisition throughout the experiment (right).

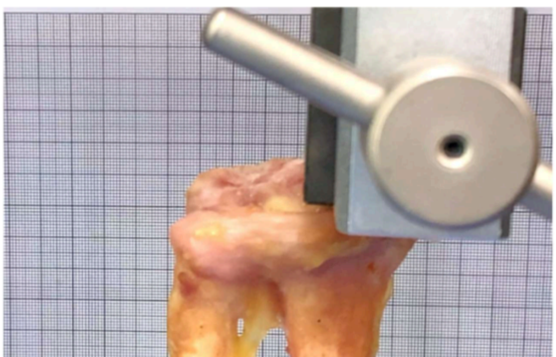


Figure 8. Calibrated graph paper used as a reference for measuring longitudinal displacement of the distal radius.

Statistical Analysis

A sample size of 10 specimens was calculated to provide 80% power to detect a significant difference of 0.9 standard deviations at a significance level of $p \leq 0.05$.[14] The normality of the data distribution for each parameter was assessed using the Kolmogorov–Smirnov test. Student's *t*-tests were used to analyze differences in forearm rotational changes between each sequential sectioning stage. Repeated-measures ANOVA was applied to compare forearm longitudinal displacement across the sectioning sequence in the three forearm positions (neutral, pronation, and supination). Bonferroni post hoc tests were performed to evaluate differences between the intact condition and each sequential sectioning stage.

Results

Forearm rotational stability

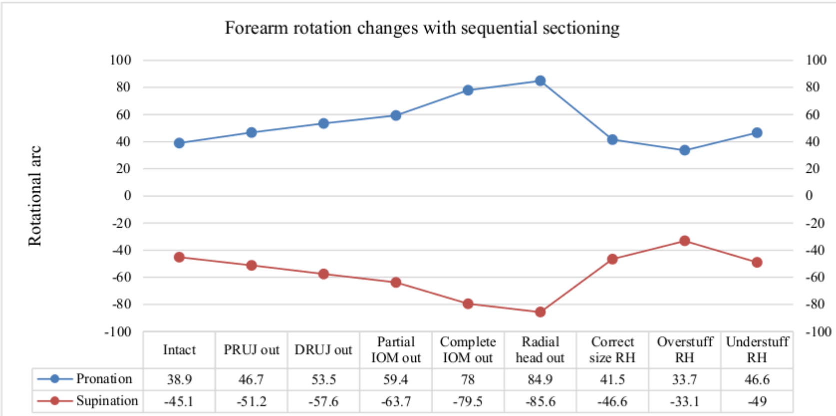
Serial sectioning resulted in progressively increasing rotational arc changes (Table 1, Figure 9). Sectioning of the PRUJ or DRUJ alone produced a 33% increase in the forearm rotational arc compared to the intact state. Subsequent partial and complete sectioning of the interosseous membrane (IOM) further increased the rotational arc by 47% and 87%, respectively. When the radial head was resected, simulating an Essex-Lopresti injury, the total rotational arc increased by 102% relative to the intact condition. Across all sectioning stages, the rotational arc was consistently greater in supination compared to pronation.

Table 1. Changes in forearm rotational arc with sequential sectioning.

	Intact	PRUJ out	DRUJ out	Partial IOM out	Complete IOM out	Radial head out	Radial head replacement with IOM reconstruction	Over-stuff radial head replacement	Under-stuff radial head replacement
Total rotational arc	84.0 (71 - 109)	97.9 (86 – 120)	113.7 (99 – 130)	125.3 (114 – 138)	159.5 (138 – 170)	171.1 (153 – 180)	90.0 (73 – 120)	66.8 (52 – 77)	95.5 (83 – 115)
P value		**0.019**	**0.000**	**0.000**	**0.000**	**0.000**	0.518	**0.003**	0.109

Statistically significant for $p < 0.05$ (student t-test was performed for each condition compare to intact condition)

Figure 9. Changes in forearm pronation and supination following sequential sectioning of the forearm stabilizing structures.



*The supination was reported in negative value for presentation.

Forearm longitudinal stability

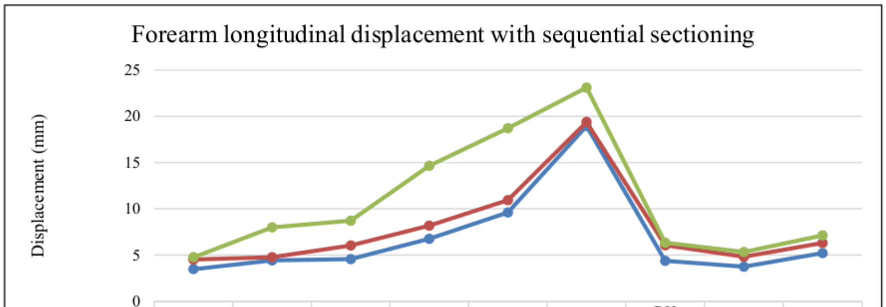
Serial sectioning resulted in progressively increasing longitudinal displacement of the forearm (Table 2, Figure 10). There was a statistically significant effect of sequential sectioning on longitudinal displacement, Wilks' Lambda = 0.046, $F(2, 80) = 833.725$, $p < 0.001$. Sectioning of the PRUJ or DRUJ alone produced a 30% increase in longitudinal displacement compared to the intact state. Additional partial and complete IOM sectioning further increased displacement by 100% and 200%, respectively. When the radial head was removed, simulating an Essex-Lopresti injury, displacement increased by 435% relative to the intact condition. Across all sectioning stages, longitudinal displacement was consistently greater in the supination position compared to pronation.

Table 2. Forearm longitudinal displacement across three positions following sequential sectioning of stabilizing structures.

Sequences of sectioning	Displacement (mm) (range) measured in each forearm position			p-values
	Neutral	Pronation	Supination	
Intact	3.48 (2.7 – 5.4)	3.48 (2.7 – 5.4)	3.48 (2.7 – 5.4)	
PRUJ out	4.41 (3.5 – 6.9)	4.78 (3.8 – 7.6)	7.99 (6.9 – 11.0)	0.828
DRUJ out	4.56 (3.5 – 7.0)	6.04 (5.0 – 8.9)	8.71 (7.2 – 15.9)	**0.035**
Partial IOM out	6.76 (5.6 – 10.3)	8.18 (6.9 – 12.7)	14.54 (12.9 – 18.4)	**0.000**
Complete IOM	9.60 (8.2 – 15.7)	10.93 (9.2 – 17.2)	18.71 (17.2 – 21.1)	**0.000**
Radial head out	18.95 (17.6 – 22.0)	19.38 (17.8 – 24.1)	23.11 (21.9 – 28.0)	**0.000**
Radial head replacement with IOM reconstruction	4.37 (4.0 – 6.0)	6.06 (4.9 – 7.4)	6.34 (5.2 – 7.5)	1.000
Over-stuff radial head replacement	3.75 (2.9 – 7.0)	4.81 (4.0 – 8.4)	5.33 (4.4 – 10.2)	1.000
Under-stuff radial head replacement	5.21 (4.5 – 6.7)	6.31 (5.5 – 7.2)	7.14(5.5 – 8.0)	0.165

Statistically significant if $p < 0.05$ (Bonferonni post-hoc between intact condition and each sequence of sectioning).

Figure 10. Forearm longitudinal displacement measured in three positions (neutral, pronation, supination) after sequential sectioning of forearm stabilizing structures.



	Intact	PRUJ	DRUJ	Partial IOM	Complete IOM	RH out	RH correct size	Overstuff RH	Understuff RH
Neutral	3.48	4.41	4.56	6.76	9.6	18.95	4.37	3.75	5.21
Pronation	4.52	4.78	6.04	8.18	10.93	19.38	6.06	4.81	6.31
Supination	4.76	7.99	8.71	14.65	18.71	23.11	6.34	5.33	7.14

Discussion

The most important finding of this study was that loss of forearm stabilizing structures led to progressive increases in both longitudinal translation and rotational instability. The longitudinal displacement of the forearm increased proportionally with the cumulative number of disrupted stabilizing structures.

The clinical implication of this finding is the potential to provide a practical diagnostic reference when evaluating forearm instability. In addition to obtaining a thorough patient history and performing a detailed physical examination, radiographic imaging extending from the elbow to the wrist—on both the affected and contralateral sides—can help assess evidence of forearm instability.[19] Static anteroposterior and lateral forearm radiographs are useful for detecting ulnar-positive variance. However, no specific threshold of ulnar-positive variance has been defined to represent the severity of injury to the forearm stabilizers.

The longitudinal displacement measurements obtained in the present study may serve as a surrogate marker for ulnar-positive variance in the clinical setting. Based on our results, the cumulative extent of structural disruption can be grouped into four stages, each contributing progressively to the degree of ulnar-positive variance (Table 3).

Table 3. Stages of forearm longitudinal instability and corresponding degrees of ulnar variance.

Stages of forearm longitudinal instability	Degree of Ulnar-variance
Stage 1: PRUJ and DRUJ insult	30% increase
Stage 2: Stage 1 with Partial IOM insult	100% increase
Stage 3: Stage 2 with Complete IOM insult	200% increase
Stage 4: Stage 3 with Radial head insult	435% increase

Intraoperative tests have been proposed to assess forearm instability. The “radius pull test,” described in cadaver models, demonstrated that applying longitudinal traction to the radius resulting in more than 3 mm of proximal migration indicates disruption of the interosseous membrane (IOM).[18] Similarly, the “radius joystick test,” also described in cadaver models, involves applying lateral traction to the radial neck while the forearm is maximally pronated; lateral displacement of the radius suggests IOM disruption.[20]

However, these tests do not evaluate the forearm’s ability to withstand axial load, and as a result, partial IOM disruptions may go undetected. If partial IOM injury is under-recognized, radial head removal can further compromise the remaining IOM fibers, leading to forearm instability. Importantly, unlike the radius pull test, which provides a fixed threshold (3 mm) as a diagnostic cutoff, the relative values (percentage increases) reported in the present study may allow for broader generalizability across diverse patient populations and forearm sizes.

The range of motion during forearm rotation has been a key focus of biomechanical studies, particularly in relation to distal radioulnar joint (DRUJ) injury. Experimental setups typically involve measuring the rotational arc following serial sectioning of the soft tissue stabilizers of the DRUJ to identify which structures are most critical for limiting forearm motion.[9]

In our study, the intact forearm positioned in 90° of elbow flexion demonstrated an average rotational arc of approximately 84°. This value was higher compared to previously reported studies, likely due to differences in elbow positioning.[9, 21] We specifically positioned the specimens at 90° of elbow flexion to simulate the clinical conditions of in-office physical examination.

The observed increases in rotational arc across all specimens following sequential sectioning of the forearm stabilizing structures highlight the critical role these structures play in maintaining rotational stability (Table 4). The clinical implication of these findings is that rotational examination of the forearm under general anesthesia can be a useful diagnostic tool, particularly when Essex-Lopresti injury is suspected, and should be compared with the contralateral, uninjured forearm.

Table 4. Stages of forearm rotational instability and associated rotational arc changes.

Stages of forearm rotational instability	Increase of rotational arc
Stage 1: PRUJ and DRUJ insult	33%
Stage 2: Stage 1 with Partial IOM insult	47%
Stage 3: Stage 2 with Complete IOM insult	87%
Stage 4: Stage 3 with Radial head insult	102%

The forearm is described as a functional joint composed of a tri-articular complex—the proximal radioulnar joint (PRUJ), middle radioulnar joint (MRUJ), and distal radioulnar joint (DRUJ)—which share a single axis of rotation that must remain both stable and mobile to allow a full range of motion.[22, 23] Injury to any one component of this complex can compromise overall forearm stability, altering both force transmission and rotational mechanics.[23]

Previous studies have reported that the combination of radial head replacement and IOM reconstruction can restore distal ulnar loading forces[17] and forearm stiffness[5] to a near-normal levels[24, 25]. However, these studies often lacked a clearly defined experimental approach addressing all three components of the forearm complex (PRUJ, MRUJ, DRUJ) and did not specifically assess longitudinal radioulnar displacement or rotational instability in a way that could be directly applied to clinical decision-making after forearm stabilization procedures for Essex-Lopresti injuries.

The present study demonstrates that using an appropriately sized radial head prosthesis in combination with IOM reconstruction effectively restores both longitudinal and rotational forearm stability following an Essex-Lopresti injury model. Importantly, this study also provides a clinically useful reference to help guide surgeons in managing Essex-Lopresti injuries, particularly when radial head replacement is indicated.

There were several notable limitations in our study. First, the small sample size and the advanced mean age of the cadaveric specimens may limit the generalizability of the findings to younger or more diverse populations. Second, removal of the forearm musculature may have altered the native kinematics of the elbow and forearm, potentially underestimating or overestimating stability. Third, the use of standardized axial loading and rotational torque values, while necessary for consistency, may not fully reflect the variability of forces encountered in vivo, which could limit the direct clinical translation of the data.

Despite these limitations, the study has several important strengths. First, the experimental design comprehensively included all three major stabilizing components of the forearm: the PRUJ, DRUJ, and MRUJ. Second, both rotational and longitudinal displacement tests were conducted using a mechanical testing system, minimizing the risk of observer bias. Third, the study provides clinically relevant diagnostic insights: longitudinal displacement can potentially be assessed through imaging, while rotational instability can be evaluated through physical examination.

Future research should focus on in vivo studies to validate the degree of forearm translation and rotation in patients with confirmed Essex-Lopresti injuries and compare these findings with the contralateral, uninjured limb. Such studies would help support the clinical use of these measurements as a screening tool for diagnosing forearm instability.

Conclusions

Loss of forearm stabilizing structures results in both longitudinal translation and rotational instability. In the Essex-Lopresti injury model, forearm rotation and longitudinal translation increased approximately twofold and fourfold, respectively, compared to the intact forearm. Radial head replacement combined with interosseous membrane (IOM) reconstruction effectively restored both longitudinal and rotational stability to near-normal levels.

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Figure and table captions

Figure captions

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Figure 9. Changes in forearm pronation and supination following sequential sectioning of the forearm stabilizing structures.

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Table captions

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Table 2. Forearm longitudinal displacement across three positions following sequential sectioning of stabilizing structures.

Table 3. Stages of forearm longitudinal instability and corresponding degrees of ulnar variance.

Table 4. Stages of forearm rotational instability and associated rotational arc changes.

References

1. Shepard MF, Markolf KL, Dunbar AM. The effects of partial and total interosseous membrane transection on load sharing in the cadaver forearm. *J Orthop Res.* 2001;19:587-592.
2. Rabinowitz RS, Light TR, Havey RM, et al. The role of the interosseous membrane and triangular fibrocartilage complex in forearm stability. *J Hand Surg Am.* 1994;19:385-393.
3. Kihara H, Palmer AK, Werner FW, Short WH, Fortino MD. The effect of dorsally angulated distal radius fractures on distal radioulnar joint congruency and forearm rotation. *J Hand Surg Am.* 1996;21:40-47.
4. Schneiderman G, Meldrum RD, Bloebaum RD, Tarr R, Sarmiento A. The interosseous membrane of the forearm: structure and its role in Galeazzi fractures. *The Journal of trauma.* 1993;35:879-885.
5. Sellman DC, Seitz WH, Jr., Postak PD, Greenwald AS. Reconstructive strategies for radioulnar dissociation: a biomechanical study. *Journal of orthopaedic trauma.* 1995;9:516-522.
6. Skahen JR, 3rd, Palmer AK, Werner FW, Fortino MD. Reconstruction of the interosseous membrane of the forearm in cadavers. *J Hand Surg Am.* 1997;22:986-994.
7. Skahen JR, 3rd, Palmer AK, Werner FW, Fortino MD. The interosseous membrane of the forearm: anatomy and function. *J Hand Surg Am.* 1997;22:981-985.
8. Essex-Lopresti P. Fractures of the radial head with distal radio-ulnar dislocation; report of two cases. *The Journal of bone and joint surgery. British volume.* 1951;33B:244-247.
9. Ward LD, Ambrose CG, Masson MV, Levaro F. The role of the distal radioulnar ligaments, interosseous membrane, and joint capsule in distal radioulnar joint stability. *J Hand Surg Am.* 2000;25:341-351.
10. Malone PS, Cooley J, Morris J, Terenghi G, Lees VC. The biomechanical and functional relationships of the proximal radioulnar joint, distal radioulnar joint, and interosseous ligament. *J Hand Surg Eur Vol.* 2015;40:485-493.
11. Masouros PT, Apergis EP, Mavrogenis AF, Babis GC, Artemi DK, Nikolaou VS. Reconstruction of the forearm interosseous membrane: a biomechanical study of three different techniques. *J Hand Surg Eur Vol.* 2020;45:360-368.
12. Kholinne E, Kwak JM, Sun Y, Koh KH, Jeon IH. The role of the interosseous ligament in forearm rotation: A bio-mechanical study. *J Orthop Surg (Hong Kong).* 2020;28:2309499020973481.

13. Tay SC, van Riet R, Kazunari T, Amrami KK, An KN, Berger RA. In-vivo kinematic analysis of forearm rotation using helical axis analysis. *Clinical biomechanics (Bristol, Avon).* 2010;25:655-659.

14. Hwang JT, Kim Y, Shields MN, et al. Effects of axial forearm instability on force transmission across the elbow. *J Shoulder Elbow Surg.* 2019;28:170-177.

15. Rausch V, Wegmann S, Hackl M, et al. Insertional anatomy of the anterior medial collateral ligament on the sublime tubercle of the elbow. *Journal of shoulder and elbow surgery.* 2019;28:555-560.

16. Markolf KL, Dunbar AM, Hannani K. Mechanisms of load transfer in the cadaver forearm: role of the interosseous membrane. *J Hand Surg Am.* 2000;25:674-682.

17. Tejwani SG, Markolf KL, Benhaim P. Graft reconstruction of the interosseous membrane in conjunction with metallic radial head replacement: a cadaveric study. *J Hand Surg Am.* 2005;30:335-342.

18. Smith AM, Urbanosky LR, Castle JA, Rushing JT, Ruch DS. Radius pull test: predictor of longitudinal forearm instability. *The Journal of bone and joint surgery. American volume.* 2002;84:1970-1976.

19. Loeffler BJ, Green JB, Zelouf DS. Forearm instability. *The Journal of hand surgery.* 2014;39:156-167.

20. Soubeyrand M, Ciais G, Wassermann V, et al. The intra-operative radius joystick test to diagnose complete disruption of the interosseous membrane. *The Journal of bone and joint surgery. British volume.* 2011;93:1389-1394.

21. Gutowski CJ, Darvish K, Ilyas AM, Jones CM. Interosseous Ligament and Transverse Forearm Stability: A Biomechanical Cadaver Study. *The Journal of hand surgery.* 2017;42:87-95.

22. Soubeyrand M, Wassermann V, Hirsch C, Oberlin C, Gagey O, Dumontier C. The middle radioulnar joint and triarticular forearm complex. *J Hand Surg Eur Vol.* 2011;36:447-454.

23. Orbay JL, Cambo RA. Biomechanical Factors in Stability of the Forearm. *Hand Clin.* 2020;36:407-415.

24. Kam CC, Jones CM, Fennema JL, Latta LL, Ouellette EA, Evans PJ. Suture-button construct for interosseous ligament reconstruction in longitudinal radioulnar dissociations: a biomechanical study. *The Journal of hand surgery.* 2010;35:1626-1632.

25. Jones CM, Kam CC, Ouellette EA, Milne EL, Kaimrajh D, Latta LL. Comparison of 2 forearm reconstructions for longitudinal radioulnar dissociation: a cadaver study. *The Journal of hand surgery.* 2012;37:741-747.

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