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Essex-Lopresti injuries: an update

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■ Reconstruction of the central band of the interosseous membrane is an emerging procedure implemented in the treatment of longitudinal radioulnar dissociation (LRUD), usually in its chronic setting, after Essex-Lopresti injuries of the forearm.

■ There are no sufficient clinical data to support reconstruction of the central band of the interosseous membrane in acute LRUD injuries.

■ Clinical and cadaveric studies comparing autografts (palmaris longus, flexor carpi radialis and bone-patellar-bone), allografts (Achilles tendon) and synthetic ligaments have not shown superiority of one technique *versus* another; however, they have shown special concerns with respect to the use of synthetic grafts.

■ Iatrogenic fracture, decrease of rotational range of movement, iatrogenic nerve injury (superficial radial and median nerve), donor site morbidity with autografts and recurrent instability are the complications reported in literature after interosseous membrane reconstruction.

Introduction

Essex-Lopresti injury or longitudinal radioulnar dissociation (LRUD) occurs when a high-energy load is axially applied on the forearm, usually as a result from a fall on an outstretched hand. The pattern of the injury consists of a fracture of the radial head (RH), disruption of distal radioulnar joint (DRUJ) and rupture of the interosseous membrane (IOM).[1] This can be a disabling injury with devastating complications, if either missed or poorly treated. Unfortunately, the true extent of the injury is usually underestimated, with rates of missed diagnosis exceeding 60% in most series.[2] Instability may be evident acutely; however, more commonly it evolves over time, due to an overlooked partial tear of the IOM.[3,4]

Peter Gordon Essex Lopresti had already emphasized in 1951 the importance of RH repair or reconstruction in order to prevent proximal migration of the radius and longitudinal instability.[1] In addition to length restoration, re-establishment of the radiocapitellar joint and DRUJ reduction, which are the basic principles of management, the need to reconstruct the IOM has been emphasized by many surgeons.[3,5,6] Yet, the indications of IOM reconstruction have not been defined. Regarding the technique, both autografts and synthetic ligaments have been used in various techniques; although numerous experimental cadaveric studies have been performed, there is a relative scarcity of clinical data.[7–12]

This article reviews the related literature with respect to Essex-Lopresti injury, central band (CB) and IOM reconstruction, IOM reconstruction, longitudinal radioulnar instability and LRUD, to provide a better understanding of forearm biomechanics, and thereafter of Essex-Lopresti injury, and to discuss the indications, available reconstruction options and surgical techniques described in literature with respect to IOM reconstruction.
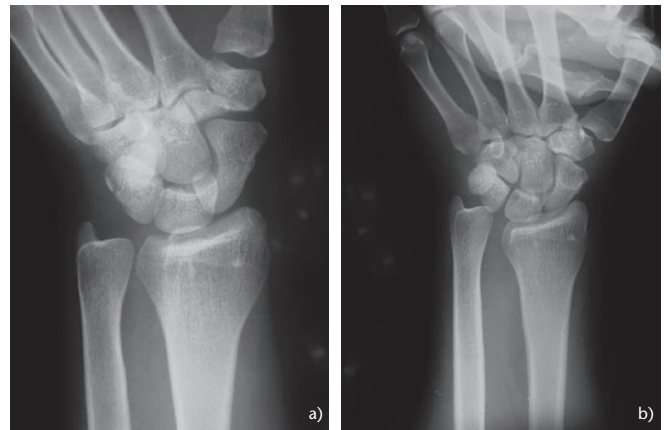
Anatomy and biomechanics of the IOM

The forearm should be considered a unit that consists of the radius and the ulna, bound together proximally by the proximal radioulnar joint (PRUJ), distally by the DRUJ and centrally by the IOM or middle radioulnar joint.[13] The IOM is a complex structure comprising both ligamentous and

Fig. 1 Dissection of a cadaveric specimen depicting the anterior aspect of the IOM. Accessory bands are not always easily distinguished from CB.


Fig. 2 Instability is not always evident. (a) Standard and (b) dynamic (stress) radiographs show the extent of instability after an Essex-Lopresti injury.

membranous elements (Fig. 1). Noda et al[14] identified five distinct components of the IOM: 1) the CB running obliquely and distally from the radius to ulna with an orientation of 20° to 24° with respect to the long axis of the ulna; 2) the proximal oblique cord on the anterior aspect; 3) the dorsal oblique accessory cord; 4) the accessory band; and 5) the distal membranous portion that contributes to DRUJ stability. The CB is the most consistent structure, being the widest (9.7 ± 3 mm) and thickest part of the IOM (1.3 ± 0.2 mm).[14] Its origin is located volarly at approximately 60% of the radial length as measured from the radial styloid and inserts dorsally at one-third of the ulnar length from the ulnar head.[3,7,8]

The oblique orientation of the CB fibres reflects its biomechanical action that can be analysed into two vectors: a longitudinal that resists to longitudinal dissociation forces; and a smaller horizontal that prevents transverse radioulnar splaying during axial loading.[13,15] Although the longitudinal stability of the forearm is primarily provided by the RH, with the CB and the DRUJ acting as secondary stabilizers,[5,16,17] the role of the CB emerges after RH resection, as it becomes the primary stabilizing component. Hotchkiss et al[18] demonstrated that after RH excision the IOM transmits about 90% of forces during axial loading through the forearm and contributes by 75% to its mechanical stiffness. Moreover, the CB accommodates load transmission from the distal radius to the proximal ulna; the radiocarpal joint carries approximately 80% of the load through the wrist, while the radiocapitellar joint

approximately 60% (51% to 70) of the load.[5,16,17,19] Nevertheless, many factors affect the precise amount of load distribution; these include the ulnar variance, degree of forearm rotation, position of the wrist, varus/valgus position of the elbow and pattern of the applying load.[16–19]

Diagnosis

Early recognition of IOM tears may be the key to avoid complications and obtaining favourable outcomes; however, in the acute setting, there may be only subtle findings indicative of instability (Fig. 2).[5,7] Therefore, a high index of clinical suspicion is required. Every RH fracture should alert the surgeon to look for signs of an Essex-Lopresti injury; tenderness over the dorsal midshaft of the forearm should raise suspicions for a likely IOM rupture, while the wrist should be thoroughly evaluated for pain on palpation, fovea sign or instability. In the presence of clinical suspicion, a complete set of elbow, forearm and wrist radiographs in both planes should be obtained.[4,5,7] Bilateral radiographs will allow for comparison of the ulnar variance with the uninjured wrist; the anteroposterior grip view of the wrist in pronation is very helpful to assess dynamic instability by measuring the change in ulnar variance.[20] Yet, the surgeon must be aware of the fact that wrist radiographs may be normal on initial presentation.

Advanced imaging modalities, such as MRI and ultrasound, have emerged as valuable diagnostic tools for IOM tears with sensitivity rates > 88% in most series.[5] The 'muscular hernia sign' can be elicited in the presence of an IOM tear by applying a force from anterior to posterior, with the herniated musculature being easily visible also by ultrasound on the posterior aspect of the forearm.[21] Nonetheless, longitudinal stability should be always evaluated
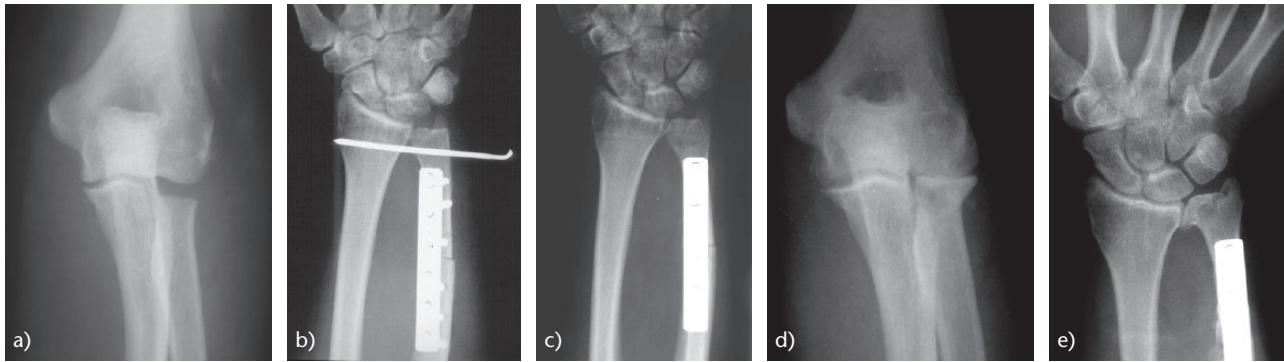
Fig. 3 The sequelae of a missed Essex-Lopresti injury. (a) The patient was initially treated with RH excision. (b) Radiograph of the wrist after one year shows a grossly positive ulna. (c) Ulna shortening osteotomy and DRUJ pinning was done. Radiographs at five-year follow-up show (d) recurrent instability with advanced radiocapitellar arthritis and (e) DRUJ arthritis.

intra-operatively as well. The 'radius pull test' is considered positive when a > 3 mm proximal migration of the radius is observed after applying manual traction to the radius via a bone tenaculum suggesting a possible IOM tear, while a proximal migration of > 6 mm indicates injury to both TFCC and IOM strongly suggesting longitudinal instability.[22] The intra-operative joystick test describes the application of lateral traction to the radial neck in full pronation while looking for lateral translation of the radius; it has been suggested to be a sensitive and reproducible test.[23]

Indications for CB reconstruction

The decision of whether to reconstruct the CB is dictated by the time of diagnosis, the chronicity of the lesion and the functional demands of the patient. LRUD in its chronic setting is indisputably the primary indication for CB reconstruction.[3,7,8] The typical scenario involves an ironically excised RH in the presence of an unrecognized partial tear of the IOM. In this case, the IOM fails to resist to the longitudinal forces through the forearm and progressively evolves to complete rupture.[3,7] The sequelae of proximal migration of the radius, ulnar abutment syndrome and longitudinal instability are common findings (Fig. 3). It should be emphasized that for every 1 mm of proximal radial migration, a 10% increase in load across the distal ulna is expected.[24] CB reconstruction in these cases is strongly indicated in order to restore longitudinal stability, decrease distal ulnar impaction forces and offload the radiocapitellar joint.

The reducibility of the radius migration should also be addressed.[7] In most cases, an ulnar shortening osteotomy is required in order to level the DRUJ.[7,8] In the acute setting, treatment strategy traditionally involves fixation or replacement of the RH along with DRUJ reduction and TFCC repair. Many surgeons agree that this protocol yields favourable outcomes in a significant percentage of patients.[4,7] Yet, these procedures alone cannot effectively restore the normal mechanics of the forearm, since the load transfer through the IOM ceases. Even if the RH is fixed or replaced, a longitudinal radioulnar displacement can occur after axial loading.[25,26] In any case, the excessive forces through the radiocapitellar joint predispose for early implant instability, arthritis and pain.[17,19,27] Additionally, the low healing potential of the CB preclude the possibility that the CB will heal on its own.[7] This fact suggests a possible role for IOM reconstruction even in the acute phase.[5,6] Still, there are no sufficient clinical data to support a CB reconstruction as a standard part of the treatment of acute LRUD.

Surgical techniques: cadaveric studies

The biomechanical effect of IOM reconstruction came to light in 1995 by Sellman et al[28] who attempted to simulate radioulnar dissociation in cadavers by excising the RH and sectioning the central 10 cm of the IOM. They showed that reconstruction of the IOM with a polyester cord alone could restore the stiffness of the forearm by 94%, while the addition of a RH titanium implant increased stiffness to 145% of normal. Since then, many researchers evaluated the biomechanical benefits of CB reconstruction measuring either load transmission through the forearm or radiological parameters.[25–37]

The rationale of the majority of biomechanical studies is to apply an axial load to the specimen through the palm and measure the distal ulna and/or proximal radius forces in three states: 1) intact; 2) after sectioning the IOM; and 3) after CB reconstruction with a graft.[25–34] Skahen et al[29] investigated experimentally the use of the flexor carpi radialis (FCR) tendon as an autograft in RH-deficient cadavers after sectioning the IOM; although reconstruction of the CB with a single-bundle FCR tendon prevented proximal migration of the radius, it was insufficient in restoring completely the longitudinal stability of the forearm. Nine

Table 1. Summary of the most important published clinical studies and technical notes on Essex-Lopresti injury

| Studies	Type of study	Graft for reconstruction	Patients (n)	Outcomes	Comments
Marcotte and Osterman[7]	Prospective clinical study	BPB tendon autograft	16	Improved grip strength, ulnar variance and pain relief	No patient received a RH replacement; 25% knee discomfort
Chloros et al[8]	Technical note	Pronator teres autograft	Not reported	Not reported	Technically demanding
Adams et al[3]	Technical note	BPB tendon allograft	1	Improved ROM; no DRUJ instability; clinical improvement	No knee discomfort; no donor site morbidity
Sabo et al[10]	Clinical series	Synthetic ligament	4	Mixed results	All patients had undergone previous surgery
Brin et al[11]	Case study	Tightrope	1	Excellent ROM	The only case of acute Essex-Lopresti lesion
Gaspar et al[9]	Retrospective clinical study	Mini Tightrope	10	Improved DASH scores grip strength and ulnar variance	Three patients needed re-operation
Meals et al[6]	Review article/Case study	Suture-button construct	1	Pain relief, improved cosmesis	Concerns about long-term stability
Miller et al[12]	Technical note/Case study	Anterior tibialis allograft	1	Normalization of radiological parameters, pain relief	Superior mechanical properties of the graft
Bigazzi et al[39]	Technical note	Folded fascia lata allograft	1	Improved elbow, forearm, and wrist ROM; pain relief; normal grip and pinch strength; normal radiographs	Reproducibility; no donor site morbidity

years later, Pfaelle et al[30] suggested the use of a double-bundle instead of a single-bundle FCR tendon autograft; they found that a single-bundle graft could restore 75% of the normal load transfer, whereas a double-bundle technique restored the load transfer to the level of the intact IOM.[30] However, all these data remain experimental, since an FCR autograft has never been implemented in clinical studies to our knowledge.

The findings of Tomaino et al[19] regarding Achilles tendon allograft reconstruction of the CB were consistent with those of other researchers; an Achilles-allograft could re-establish the load transmission from the radius to the ulna in cadaveric specimens after excision of the IOM, but only to an extent of 50% compared to the native IOM. Ligamentoplasty using the semitendinosus tendon was described by Soubeyrand et al[35] who found that it can decrease effectively longitudinal forces on the radius, with a mean load of failure of 28 kg, rendering it a reliable option for clinical application.

The use of bone-patellar-bone (BPB) tendon autograft has also been described.[26,31–33] Stabile et al[31] compared the structural properties of BPB graft with Achilles tendon and FCR grafts and found that all three structures were inferior to the native IOM, although the BPB tendon was slightly stiffer than the other two. Another biomechanical study comparing three tendon autografts (palmaris longus, FCR and BPB) yielded similar results.[32] It was shown that the patellar tendon could prevent proximal migration of the radius in RH-deficient cadaveric arms more effectively than the other grafts, but none of them was capable of restoring normal mechanics of the forearm.[32] In another study, it was suggested that a RH arthroplasty in LRUD should be combined with a reconstruction procedure, as it can significantly reduce distal ulnar force.[26,33] In fact, force transmission through the distal ulna was measured

after CB reconstruction with and without a RH prosthesis; although the RH implant was the most important component in restoring longitudinal stability, the addition of a reconstruction procedure decreased the distal ulnar forces to normal levels.[26]

The use of synthetic ligaments has also been studied.[6,25,34] In a similar cadaveric study, Kam et al[25] measured both distal ulnar impaction forces and radioulnar displacement and found that 17% of the forces were transmitted through the distal ulna in intact specimens, which increased to 52% after forearm destabilization. After reconstructing the CB with a mini Tightrope® (Arthrex, Inc., FL, USA), the forces were reduced to 19%, while the addition of a RH prosthesis achieved a further reduction to 13.7%. Radioulnar displacement at the wrist was significantly lower after CB reconstruction, but not to the level of the intact status.[25] Similarly, Drake et al.[34] measured the radioulnar displacement after excising the RH, cutting the IOM and reconstructing it with the use of a suture-button construct. They found that the suture-button construct could prevent proximal migration of the radius effectively even without a RH replacement. However, concerns over long-time stability were expressed by authors, since no biologic integration of the graft is expected.[34] A double-bundle technique using a second Tightrope 1 cm proximal and parallel to the first, does not provide statistically significant difference in longitudinal stability, as demonstrated by Hackl et al.[36] However, it might be more reliable, without affecting adversely the rotational ROM of the forearm. Recently, Dayan et al.[37] described a more sophisticated technique, which also addresses the need for proximal and DRUJ stabilization. They combined a typical reconstruction of the CB with a transverse DRUJ ligamentoplasty plus annular ligament repair using a ligament advanced reinforcement system
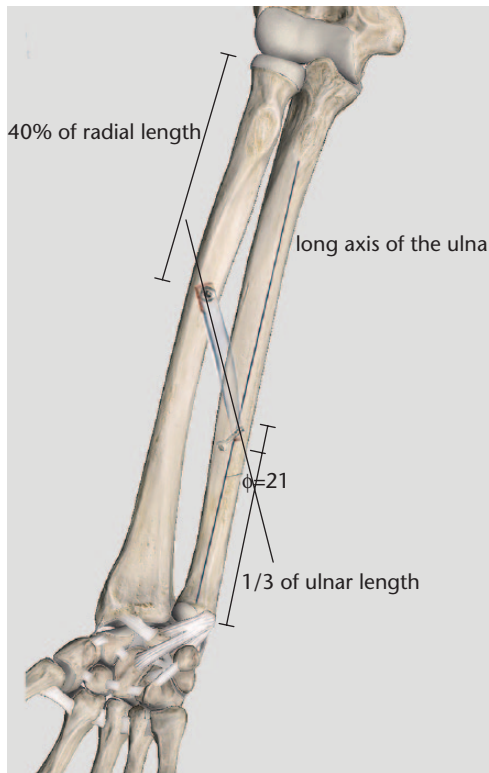
Fig. 4 A schematic drawing shows the ideal trajectory of the graft for CB reconstruction.

(LARS) artificial ligament. This procedure managed to restore both longitudinal and DRUJ stability of the forearm in cadavers and could be an interesting option for the treatment of Essex-Lopresti injuries.

Surgical techniques: clinical studies

There are few published clinical studies reporting on CB and IOM reconstruction in patients with Essex-Lopresti injuries (Table 1). It was not until 2007 that Marcotte and Ostermann published their results of a preliminary prospective series of 16 patients treated for chronic longitudinal radioulnar instability.[7] They introduced the reconstruction of the CB with a BPB autograft along with an ulnar shortening osteotomy, without a RH replacement. A BPB tendon autograft was harvested and passed through a dorsal plane under the extensor musculature from distal ulna to proximal radius. The graft was secured to bone with screws, once appropriate troughs had been created to both bones. They reported very good functional and radiological results; the ulnar variance was corrected and grip strength improved from 59% to 86% of the unaffected limb in the majority of patients, while no secondary surgery for recurrent instability was needed. However, 25% of the patients complained about knee discomfort from BPB graft harvesting.[7]

A technique that used a rerouting procedure of the pronator teres tendon (PT) has also been described.[8] The PT tendon is transected at its musculotendinous junction and rerouted in an oblique and distal direction to the ulna. Concomitant procedures, according to these authors, should include RH replacement, an ulnar levelling osteotomy and TFCC repair.[8] The graft can be secured to the distal ulna by suturing it through the holes of the ulnar shortening osteotomy plate or by using two bone anchors.[8] According to the authors, adequate healing of the tendon to the periosteum was observed at the two-year follow-up; nevertheless, their study did not include any case illustration neither patient-reported outcomes. For the rest, it was underlined not only that the procedure presents technical difficulties, thus surgical experience is required, but that there is also risk of nerve injury secondary to the proximity of the median nerve between the heads of the PT.[8]

The use of various synthetic devices has become increasingly popular over the last decade.[6,9,11] Sabo et al[10] were the first to treat four patients with chronic instability by using a technique with synthetic graft. Through a double-incision technique, two bone tunnels were created through the radius and ulna, respectively. Then, a braided polyethylene graft was allowed to dock within the tunnels and secured to the bone by using two endobuttons. Their results were mixed, probably because all patients had already undergone prior surgical treatment. Brin et al[11] treated an acute Essex-Lopresi case by using a Tightrope and reported good clinical and radiological outcomes without addressing the proximal and the DRUJ. Using a similar technique combined with an ulna shortening osteotomy, Meals et al[6] achieved significant pain relief and improved cosmesis in a patient with advanced ulnar abutment symptoms on the grounds of chronic instability. Recently, Gaspar et al[9] retrospectively studied ten patients with LRUD using a mini Tightrope and reported quite satisfying outcomes in terms of clinical scores and radiological parameters. They achieved improvement in quick-DASH scores (mean difference, 48 points), grip strength (mean difference, 14 pounds) and ulnar variance (mean difference, 3.3 mm). However, three of the ten patients experienced complications, including persistent ulnar impingement, decreased supination and early post-operative fracture, necessitating a re-operation.[9] Despite the encouraging results, the authors underlined the great heterogeneity of their sample as an important limitation in that study.

Due to donor site morbidity of autografts and concerns regarding the long-term outcomes of synthetic devices, various allografts have emerged as alternative reconstruction options.[3,12,39] Some authors treated a patient 32 months after his Essex-Lopresti injury using a BPB allograft in order to avoid donor site morbidity.[3] They reported excellent clinical and radiological results and suggested

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the use of an allograft as an alternative. Miller et al[12] advocated for an anterior tibialis allograft emphasizing its superior material and structural properties. Using a similar technique, two bone tunnels were created to accommodate the ends of the graft that was secured using a biceps button distally and a tenodesis screw proximally. Alternatively, a hamstring autograft can be used in this technique. Recently, Bigazzi et al[39] described a quite reproducible technique using a folded fascia lata allograft along with a fixation device for graft tension.

Among the described procedures, the BPB tendon has been proven superior to other grafts in terms of material properties,[28,29] while it is probably the only technique with well-established clinical outcomes.[7] However, clinical application may be problematic due to donor site morbidity, fixed length of the graft and difficulty in proper graft tensioning.[12] The rerouting of the PT offers an interesting alternative, but it is rather technically demanding with limited reproducibility;[8,12] no biomechanical data are currently available, to our knowledge. Allografts could be another option to avoid donor site morbidity; however, irradiation before their use may result in partial loss of their biomechanical properties, while limited availability and additional costs should also be considered.[40] Synthetic devices such as the Tightrope are lacking evidence over their long-term outcomes, while their success relies on the ability of the IOM to heal because synthetic materials may experience fatigue over time.[6,25] However, there is strong evidence suggesting low healing potential of the CB: first, because of its composition consisting mostly of collagen with very little elastin contributions; and, second, because herniation of forearm musculature inhibits coaptation of the injured fibres.[7,9,41] Consequently, long-term outcomes of these techniques have yet to be defined.

Graft positioning

The graft for CB or IOM reconstruction should be placed in a 20° to 24° angle with respect to the long axis of the ulna, replicating the anatomy of the native CB; slight inaccuracy in the proximal distal direction may be less significant (Fig. 4).[8,38] Optimal position of the forearm during tensioning remains to some extent unclear. Farr et al[42] showed that the CB is considerably shorter in supination, suggesting this as the optimal position to tighten the graft if maximal tension is desired. Other authors showed that the CB has isometric properties during forearm rotation.[43] The majority of surgeons prefer to tighten it in neutral position to slight supination.[7–9,38] Many techniques have also been proposed for securing the graft to the bone: endobuttons,[10,11] transosseous sutures, bone anchors[38] and tenodesis screws[12] with none of them being superior

to another. Yet, the graft–bone attachment is of particular importance and needs further investigation.

Complications

The stress risers formed by the creation of the bone tunnels pose a risk for iatrogenic or early post-operative fracture.[9,12] Gaspar reported a case of a midshaft radius fracture five weeks after surgery, secondary to a low-energy fall in the setting probably of a metabolic disorder.[9] Yet, prophylactic plating of both bones is not routinely recommended, as a standard part of the treatment, as long as drill bits < 7.5 mm in diameter are used.[12]

A more transverse orientation of the graft or excessive tensioning can have an adverse impact on forearm rotation, thus decreasing rotational range of movements.[8] Iatrogenic nerve injury has also been reported, with the superficial radial nerve (during radius exposure) and the median nerve (during volar dissection) being mainly at risk.[8,38] The use of BPB tendon autograft may lead to increased rates of anterior knee pain and donor site morbidity.[3,7]

Lastly, there is always a potential risk for recurrent or residual instability due to graft elongation or failure to incorporate. However, current clinical data support zero rates of reoperation for recurrent instability, although instability is difficult to quantify after surgery.[3,9,10]

Conclusion

Treatment of longitudinal forearm instability is complex, especially in its chronic setting, with historically poor outcomes.[2] The thorough understanding of forearm biomechanics and especially of CB function has offered new treatment prospects. Although most of the data derive from experimental studies, we feel that there is strong evidence to support a reconstruction procedure as part of the treatment for Essex-Lopresti injuries, at least for chronic cases.

The combination of RH replacement with reconstruction of the CB restores radioulnar displacement and distal ulnar forces to normal or near normal levels in the majority of studies and especially in the most recent ones.[25,26,34] However, graft selection remains probably the matter of controversy. Some of them are biomechanically superior, but their clinical application can be complicated and vice versa. Despite the controversy in graft selection, most authors agree that appropriate graft tensioning and orientation are the keys to a favourable outcome.[3,7,8,12] It is a fact, however, that proper tensioning of the graft is difficult to quantify and requires surgical experience.

The biomechanical aspects of CB reconstruction have been thoroughly investigated, but the findings of relevant clinical studies are to some extent ambiguous. The low

incidence of Essex-Lopresti lesions and the great rates of delayed presentation pose significant limitations when planning relevant clinical studies. In most cases, the great heterogeneity of the samples impedes the researchers from reaching safe conclusions.[9] Moreover, the clinical significance of reconstruction procedures in acute setting is not completely clarified because such studies are missing. It sounds reasonable that restoration of normal load distribution should create a biomechanically favourable environment for the radiocapitellar joint. However, it remains questionable whether this biomechanical advantage in the acute phase outweighs the graft-related complications, increased operation time and the technical difficulties of these procedures. Future research should focus on these questions and evaluate the long-term clinical outcomes of CB reconstruction.

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