Ulnar Collateral Ligament Reconstruction: Alternative Surgical Techniques

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Introduction

By subjecting the elbow to massive valgus force during competition, throwing athletes are at risk for injury to the ulnar collateral ligament (UCL) of the elbow [1]. While a trial of nonsurgical treatment is recommended as the initial treatment for UCL injury, many of these athletes need surgical reconstruction of the UCL to return to their pre-injury level of performance. The modern surgical management of UCL injuries in throwing athletes was based upon the initial method described by Jobe et al. [2]. While the fundamental goals of reconstruction of the UCL still focus on returning the athlete to sport, the evolution of UCL reconstruction has led to research regarding almost every step of the surgery.

Research has quantified the magnitude of the forces on the elbow during the throwing motion; the late cocking and acceleration phases can result in valgus moments that near 290 N [1]. The primary restraint to valgus forces on the elbow, as seen during the overhead throwing motion, is the anterior bundle of the UCL [3]. Due to these high forces, the reconstructed ligament must achieve strength near that of the native UCL. Innovation regarding UCL reconstruction has focused on three aspects of the surgery: the type of approach, humeral graft fixation, and ulnar graft fixation. Multiple techniques have been investigated regarding the biomechanical effects of varied graft fixation methods that differ from bone tunnel figure-of-eight graft passage as initially described by Dr. Frank Jobe.

Modifications of the figure-of-eight technique have been developed to facilitate anatomic reconstruction and strength comparable to the native UCL. Furthermore, surgical techniques have also been developed to facilitate graft fixation in an expeditious and secure manner. The spectrum of humeral graft fixation have included the figure-of-eight technique, docking technique [4], interference screw fixation [5], suture anchor fixation, [6] and cortical suspensory fixation [7]. Graft fixation options for the ulna have included tunnel utilization, interference screw fixation, [8] and cortical suspensory fixation [7].

The most common UCL surgical techniques have been the figure-of-eight and the docking technique [9, 10]; however, other alternative techniques have been proposed to improve outcomes and decrease the risk for complications, such as bone tunnel fracture and failure of fixation. Two of the most common alternative techniques include interference screw and cortical suspensory fixation of the tendinous graft. The main benefits of these alternative fixation methods have been to facilitate ease of technique and limit complications, but a relative paucity of clinical outcomes data exists for these newer fixation

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methods compared to the figure-of-eight and docking techniques. The literature on these techniques has mostly focused on surgical methods and biomechanical assessments. Nonetheless, the concepts behind these UCL reconstruction techniques are important to consider, as we optimize surgical outcomes relating to UCL injuries in the future.

UCL Reconstruction: Biomechanical Assessment

Biomechanical studies have compared the various UCL reconstruction techniques with the native ligament. Additionally, the integrity of various graft constructs has been compared to established techniques. These studies have attempted to quantify the strength of the reconstruction options and the kinematics to optimize outcomes.

Much of the literature has focused on load to failure due to the considerable forces during the throwing motion [11]. Paletta et al. compared the valgus moment measured to failure of the native ligament in comparison to reconstructed ligaments using the figure-of-eight and docking techniques [12]. The native UCL had a maximal valgus moment to failure of 18.8 N m. In comparison to the figure-of-eight technique (8.9 N m), the docking technique had significantly greater maximal valgus moment to failure (14.3 N m, $p=0.0148$). The docking technique was not statistically different from the native UCL valgus moment to failure. The location of failure was most common at the suture-tendon interface for the figure-of-eight reconstructions; the docking technique failed most commonly due to suture failure. For both types of reconstructions, bone tunnel fracture was the second most common reason for loss of graft integrity. The strain of each reconstruction type was also assessed at 3 N m, with the docking technique having significantly less strain compared to the figure-of-eight technique ($p=0.378$). While research has shown excellent Conway scale outcomes with use of the figure-of-eight technique, the greater maximal valgus moment to failure and decreased strain with the docking technique has led to further research on this method over the past decade.

In a study by Armstrong et al., a biomechanical evaluation of the native ligament was compared to four reconstruction methods [13]. The four methods of UCL reconstruction included: (1) figure-of-eight technique, (2) docking technique as described by Rohrbough [4], (3) ulnar metal interference screw fixation with humeral docking technique (DANE TJ), and (4) ulnar cortical suspensory fixation with humeral docking technique. The peak load was measured to failure with the elbow flexed 90°; increasing load was applied in a cyclic manner until 5 mm of joint displacement occurred. For the native anterior bundle of the UCL, the peak load to failure was 142.5 N. All of the reconstruction techniques had a peak load to failure significantly less than the native ligament ($p=0.001$). The docking technique had a significantly greater peak load to failure in comparison to both the figure-of-eight and interference screw reconstructions. The cortical suspensory technique was found to have a significantly greater load to failure in comparison to the figure-of-eight technique.

Additionally, both the docking (701 cycles) and suspensory (703 cycles) reconstructions endured a significantly greater number of cycles before failure in comparison to the figure eight technique (333). The failure of the graft occurred at the suture-tendon interface with UCL reconstructions using the figure-of-eight, docking, and suspensory fixation methods. Grafts with interference screw fixation failed at the screw-tendon interface; two grafts actually tore during interference screw insertion and required subsequent revision with another graft to complete the biomechanical analysis.

Jackson et al. tested the load to failure in cadaver elbows using a single-bundle graft construct [7]. UCL reconstruction with bisuspensory cortical fixation was compared to the docking technique as described by Rohrbough [4]. Suspensory fixation of the proximal ends of the graft was achieved with the Arthrex ACL Tightrope RT (Arthrex, Naples, FL). The ultimate torque to failure was 25.1 N m for the docking technique and 26.5 N m for the bisuspensory fixation; these were not significantly different ($p = 0.78$). Failure occurred at the suture-tendon interface in six of six (100 %) of the cadaver elbows reconstructed with bisuspensory fixation and in five of six (83 %) of the elbows reconstructed using the docking technique, with the remaining failure occurring as an ulnar bone bridge fracture. For both reconstruction types, valgus laxity was similar to the elbow with a native UCL from 0 to 120° of elbow range of motion.

Reconstruction of the UCL using interference screw fixation was evaluated by Ahmad et al. [5]. In their study, the native ligament was compared with UCL reconstruction using interference screw fixation for both humeral and ulnar graft fixation. A doubled palmaris longus graft was used and tensioned at 60°. The data demonstrated an ultimate valgus moment for intact elbows (34.0 N m) that was not significantly different from the reconstructed elbows (30.6 N m). Graft failure was most commonly due to the graft rupture (60 %) followed by ulnar tunnel fracture (20 %). The biomechanical stability of this technique and ease of interference screw insertion in the ulna has encouraged research regarding interference screw fixation in conjunction with the docking technique (DANE TJ technique).

Results of biomechanical studies are valuable, but must be subsequently supported by clinical data. No single biomechanical study can support supremacy of one type of reconstruction technique; surgeon experience and clinical research must also be used to guide which reconstruction is best for each patient. We will now discuss two of these alternative UCL reconstruction techniques that may provide successful outcomes and minimize complications in both the primary and revision surgical settings.

Surgical Approach

The patient is placed in the supine position in the surgical theater, with a hand table to support the upper extremity. A tourniquet is applied to the upper arm outside of the sterile field. After a standard sterile preparation, the patient is draped in normal fashion. Appropriate antibiotics are given for surgical prophylaxis prior to incision. The tourniquet is typically inflated to approximately 100–125 mmHg above the systolic blood pressure to control bleeding in the surgical field. Adjusted to the patient’s size, an approximately 8-cm incision is made to allow for visualization of the medial epicondyle and the proximal-medial ulna in the region of the sublime tubercle. The medial antebrachial cutaneous nerve and branches are identified and protected.

Deep dissection is then performed to expose the ulnar collateral ligament. Two surgical approaches are typically used in modern-day UCL reconstruction surgery: flexor-pronator split and flexor-pronator elevation. The flexor-pronator split approach is performed at the anterior margin of the flexor-carpi ulnaris, which targets the inter-nervous plane between the flexor digitorum superficialis and the flexor-carpi ulnaris. The flexor-pronator split approach does not require exposure in the region of the ulnar nerve or subsequent ulnar nerve transposition. The flexor-pronator elevation approach is performed more posteriorly between the humeral and ulnar heads of the flexor carpi ulnaris in the plane on the ulnar nerve; therefore, this approach requires an obligatory ulnar nerve transposition.

In both alternative UCL reconstruction techniques, routine subcutaneous ulnar nerve transposition is not necessary but may be performed depending upon the desired approach. However, ulnar nerve transposition may be considered if the patient has evidence of ulnar subluxation on physical exam, documented ulnar nerve conduction pathology, or sensory paresthesias in the ulnar nerve distribution.

Retraction of the flexor-pronator muscle group will allow visualization of the UCL. Confirmatory findings of avulsion fracture, calcifications within the ligament, pathologic ligamentous laxity, and/or ligament disruption are then evaluated. Based on patient factors and surgeon preference, the palmaris or gracilis tendon grafts are harvested in the usual manner.

Surgical Technique: DANE TJ UCL Reconstruction

Potential advantages of interference screw fixation in the ulna have led to its use in conjunction with the docking technique for humeral fixation. This combination of two concepts is referred to the DANE TJ technique, in acknowledgement of innovation by Dr. David Altchek, Dr. Neal ElAttrache, and the first professional baseball player to have UCL reconstruction, Tommy John [8]. Some surgeons have even subsequently suggested utilizing interference screws for both ulnar and humeral fixation.

The ulna is prepared by identifying the sublime tubercle for interference screw placement. The bone tunnel should be angled toward the lateral aspect of the ulna, just distal the region of the supinator crest, with a depth of 15 mm (Fig. 19.1). To prevent iatrogenic injury to the articular surface, the ulnar joint surface and the bone tunnel should be separated by 3–4 mm of subchondral bone. The diameter of the tunnel is usually equal to the diameter of the folded end of the stitched tendon graft.

Preparation of the humeral tunnel for the docking technique begins with identification of the humeral insertion of the UCL on the inferior medial epicondyle. Drilling of the docking tunnel is performed in a distal-to-proximal direction with a 4.5 mm diameter drill bit. Two exit tunnels are drilled using a 2.7 mm drill bit with the distal aspect of each tunnel meeting in the 4.5 mm tunnel. The distal tunnel size is checked to ensure proper graft docking; if needed, the tunnel size can be increased to allow for passage of the graft. A bone bridge of at least 5 mm between the 2.7 mm drill holes is needed to prevent fracture of the bone during knot tying.

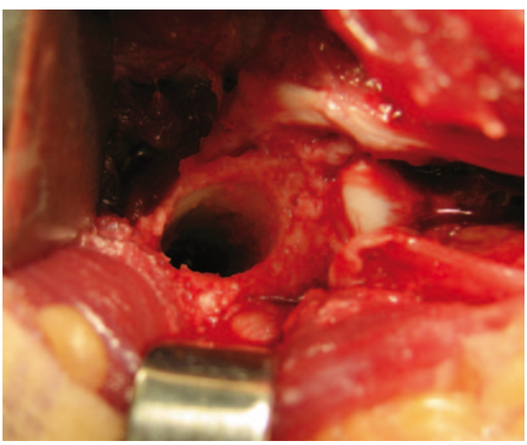

Fig. 19.1 Ulnar socket drilled in sublime tubercle. Note the preservation of bone bridge between socket and articular cartilage

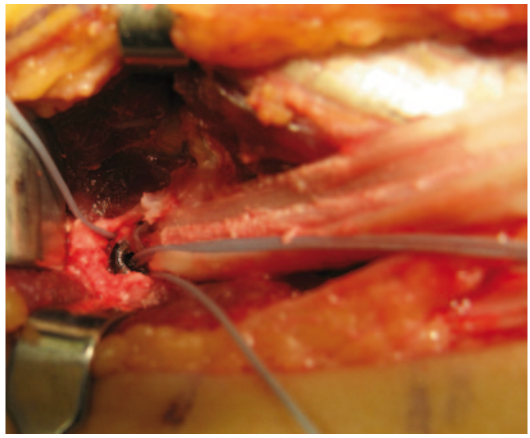

Fig. 19.2 The folded end of the graft is secured in the ulnar socket with an interference screw

Ulnar graft fixation is then performed (Fig. 19.2). The folded end of the graft is secured in the ulnar tunnel with a biotenodesis screw (Arthrex Inc, Naples, FL) that approximates the diameter of the tunnel. A smaller screw may be needed with a thicker autograft.

Humeral graft tensioning and fixation is then performed (Fig. 19.3). With the ulnohumeral joint appropriately positioned in a reduced position, the two ends of the graft are measured for proper tensioning in relation to the medial epicondyle. After removing excess tendon, the two ends of the graft are prepared with a locking stitch using a nonabsorbable suture (Number 2 Fiberwire, Arthrex Inc., Naples, FL). The respective stitch for each end of the graft is then passed through one of humeral tunnels, and the graft is seated in its ideal position. The native UCL is repaired before tensioning the graft. The suture ends are then tied over the bony bridge of the medial epicondyle with the ulnohumeral joint in a reduced position.

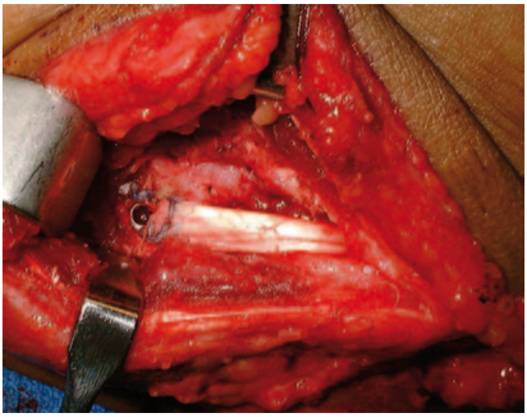

Fig. 19.3 Humeral graft tensioning and fixation is performed

Surgical Technique: Cortical Suspensory UCL Reconstruction [7]

Cortical suspensory fixation in UCL reconstruction has been adapted from the anterior cruciate reconstruction literature. In both primary UCL reconstruction and in revision cases, cortical suspensory fixation can offer an alternative graft fixation method, especially in patients with bony defects that limit fixation options at the anatomic insertions of the UCL. Either proximal or distal suspensory fixation can be used in conjunction with established techniques such as the docking technique or interference screw fixation. For patients in whom both proximal and distal suspensory fixation is additionally desired, a cortical bisuspensory technique can be used [7].

After a muscle splitting approach and identification of an incompetent UCL anterior bundle, sharp dissection is used to identify the proximal and distal insertions of the native ligament. The humeral tunnel is prepared using a 3.2 mm spade-tip pin, which is placed at the inferior medial epicondyle. The pin is left in place and over-drilled with a 4.5 mm cannulated drill to create a 15 mm bone tunnel. The cortical suspensory implant (Arthrex ACL Tightrope RT, Arthrex, Naples, FL) is passed through the bone tunnel so that the implant is secured and seated on the proximal and slightly anterior cortex of the medial column of the distal humerus. The graft is passed through the looped end of the suspension suture and folded across the loop to create a doubled graft. This humeral graft fixation technique can be used with multiple fixation options for the ulna including interference screw fixation and cortical suspensory fixation.

The ulnar tunnel at the sublime tubercle is identified to locate the desired location for tunnel placement of the distal suspensory fixation. The 3.2 mm spade-tip pin is used to guide the cortical suspensory button placement; after initial perpendicular bony penetration, the pin is directed 30° posteriorly and 30° distally. The pin is left in place to allow the 4.5 mm cannulated drill to create a bone tunnel measuring about 30 mm. The cortical suspensory implant is then passed through the tunnels and seated on the lateral ulnar cortex, with the tightrope loop resting outside of the bone tunnel. The graft is then passed through the looped end of the suspension suture and folded across the loop to create a doubled graft. The cinching suture is ready for graft seating and tensioning. Ulnar fixation with the suspensory technique can be used with various fixation options proximally, including bone tunnels, suture anchors, interference screw fixation, the docking technique, and suspensory fixation. Prior to fixation of any UCL reconstruction, the native UCL is then repaired.

In cases of bisuspensory fixation, graft tensioning and fixation have been proposed to be performed in the following fashion. The folded graft should measure approximately the same diameter as the drill bit diameter and be at least 15 cm in length. The graft should be passed through the tightrope loop of the proximal and distal suspensory fixation devices, with the graft divided into thirds at each loop location. Position the central third of the graft between the two tightrope loops; this will allow later end-to-end suturing after seating the folded graft in each tunnel. The humeral cinching suture is used to seat the proximal end of the graft by pulling in-line with graft seating. Next, the cinching suture of the ulnar suspensory implant is pulled to seat the ulnar portion of the graft, with up to 20 mm of the distal graft within the ulnar tunnel. The tensioning of the distal end of the graft within the ulna should be performed with the ulnohumeral joint reduced anatomically while maintaining a varus force at 30° of flexion. With the central third of the graft well tensioned, the proximal and distal ends of the graft should have adequate length to cross the joint line for secure fixation to each other utilizing figure-of-eight nonabsorbable sutures (Number 2 Fiberwire, Arthrex Inc., Naples, FL).

Surgical Closure and Postoperative Care

The wound is then closed in layers, beginning with the flexor-pronator mass fascia, and ending with the skin. Release of the tourniquet should be performed prior to skin closure to ensure proper hemostasis. Standard dressings are applied, and a long arm splint is applied with neutral forearm position and the elbow flexed slightly less than 90°.

The splint should be removed after 7–10 days to allow for assessment of the wound and to initiate early gently range of motion of the elbow, shoulder, and wrist. After splint removal, a hinged elbow brace can be used, but there is no consensus regarding the guidelines for utilization. In one literature review of UCL reconstruction, hinged elbow braces were used in only 139 of 351 (40%) patients [10]. Gentle strengthening of the forearm muscles can begin in the first postoperative month. However, valgus stresses on the graft should be avoided until after the second postoperative month, and throwing activities should not begin until 4 months after the reconstruction.

The postoperative rehabilitation program recommended for each reconstruction technique has many similarities; however, there is a paucity of literature describing differences in rehabilitative principles according to surgical technique. The study by Cain utilizing a figure-of-eight technique reviewed 1281 patients that were treated postoperatively with a 4-phase rehabilitation protocol as described by Wilk et al. [14]. They advocated for use of a hinged elbow brace. Full range of motion was ideally reached by 6 weeks while protecting the UCL reconstruction from valgus stress. Strengthening exercises were initiated at week 3 and were advanced at week 9. Throwing programs were typically started at week 16, and return to competition around 12 months after surgery.

Discussion

UCL reconstruction is a complex surgical procedure that is being performed with increasing frequency [9]. The surgical technique has evolved from the initial figure-of-eight technique with the goal of improving the biomechanical properties and to facilitate the ease of reconstruction. Based on the literature, the most common techniques for UCL reconstruction are the figure-of-eight and the docking techniques [9, 10]. The docking technique was an initial modification of the figure-of-eight technique that improved both the ultimate load to failure [12] and aimed to preserve some of the bone integrity through minimization of bone tunnel size. More recent advancements have focused on continued biomechanical and surgical improvements as well as focusing on creating an anatomic reconstruction.

Cadaveric studies focusing on anatomy have demonstrated that the central fibers of the anterior and posterior bands of the anterior bundle of the UCL are the most isometric division during elbow motion [15]. As opposed to the tunnels converging around the sublime tubercle on the ulnar side, single bundle reconstruction of these central fibers can be achieved with interference screw fixation as described by Ahmad [5], can be reconstructed in a doubled graft technique using the DANE TJ technique [8], or can be recreated utilizing cortical suspensory fixation.

DANE TJ UCL Reconstruction

In terms of the interference screw fixation, the DANE TJ technique allows the surgeon to use familiar concepts to facilitate a solid UCL reconstruction and has also shown good clinical outcomes. The risk of bone tunnel fracture has inspired much of the research regarding UCL reconstruction. The DANE TJ technique avoids the use of ulnar bone tunnels, which eliminates the risk of ulnar bone tunnel fracture. This avoidance of bone tunnels has led to failures of the UCL reconstructions in new locations. Biomechanical studies suggest the suture-tendon interface was a frequent location for graft failure in the figure-of-eight, docking and cortical suspensory techniques [7, 13]. The suture-tendon interface does not exist with interference screw fixation; however, failure with interference screw fixation was associated with graft rupture, ulnar tunnel fracture, and graft damage during insertion [5, 13]. Despite this limitation, graft damage during screw insertion is uncommonly reported with routine use of modern interference screw designs and materials.

The humeral docking technique component helps minimize use of large bone tunnels, which may decrease the risk of fracture. In the docking site, the graft has 360° exposure to the bone for biologic healing. Tensioning of the graft is also facilitated by pulling the sutures attached to the ends of the graft in-line through the smaller bone tunnels; secure fixation is easily achieved when tying these suture ends over the bony bridge. As reported with figure-of-eight and cortical suspensory techniques, biomechanical studies of the docking technique have also suggested that the suture-tendon interface was the most frequent location for graft failure [7, 13]. Although some advocates, therefore, suggest the utilization of interference screw fixation on the humeral side, suture-tendon interface failure has not been commonly reported in the clinical setting.

The ulnar fixation of the DANE TJ technique uses the interference screw placed at the sublime tubercle. This allows for anatomic reconstruction of the anterior bundle of the UCL using a familiar technique to many orthopedic surgeons. Biomechanically, interference screw fixation has been shown to offer a similar valgus moment to failure as the native UCL [5]. The avoidance of bone tunnels not only helps facilitate the surgery, but also allows for a doubled reconstruction of the anterior bundle in its anatomic location. However, the interference screw itself does limit the amount of bone within the tunnel available for bone-tendon healing. While offering excellent frictional fixation of the graft in a secure manner, the interference screw pressure may form an avascular zone that limits the biologic incorporation. Additionally, the interference screw may have difficulty achieving stabile fixation in revision cases with significant bone loss at the sublime tubercle.

In a clinical case series, Dines et al. described the outcomes of the DANE TJ technique in 22 patients [8]. With a mean follow-up duration of 35 months, their hybrid technique had an 86 % excellent outcome on the modified Conway scale. For the 20 athletes that participated in baseball, 17 (85 %) had an excellent result. These results are similar to other large series by Cain and Andrews [9]. Additionally, 3 of the 22 patients had revision UCL reconstruction; 2 of the 3 revision patients had an excellent result. Postsurgical ulnar nerve pathology was observed in only one revision patient who had prior UCL reconstruction and ulnar nerve transposition. Outcomes for the DANE TJ hybrid technique support its similarity to prior data regarding primary UCL reconstruction. For revision UCL reconstruction, the DANE TJ method offers an alternative technique to the traditional docking or figure eight methods.

Cortical Suspensory UCL Reconstruction

The suspensory fixation technique is a relative new type of fixation for use in UCL reconstruction. Humeral or ulnar graft fixation with suspensory fixation can aid graft tensioning by allowing graft tensioning in-line with graft seating, similar to the DANE TJ technique. By suspending the graft in the bone tunnel, a greater exposure of the graft to the bone may allow for better healing at the bone-tendon junction. Additionally, the avoidance of aperture fixation can be helpful in revision situations with bone loss at the sublime tubercle or the inferior medial epicondyle.

Despite the benefits of suspensory fixation, some limitations may exist in relation to this technology. When utilizing cortical suspensory fixation on one side (i.e., either ulnar or humeral), graft slippage may theoretically occur through the endobutton fixation. When performing a bisuspensory technique, graft slippage may also occur; however, the reconstruction also relies on suture-tendon interface fixation that may also be a source of failure. Despite these potential limitations, biomechanical studies have supported a solid fixation mechanism when utilizing the cortical suspensory technique in the setting of clinical success being reported when using this technology in other surgical procedures, including ACL reconstruction. Further research will be needed to determine if the clinical outcomes for suspensory fixation are comparable to other UCL reconstruction techniques.

Conclusion

The clinical outcomes of UCL reconstruction have been best studied regarding the figure-of-eight technique and the docking technique. Driven by the nature of these injuries during athletic performance, studies have emphasized the return to the presurgical level of sport as a holistic evaluation of the athlete's outcome after UCL reconstruction [16]. Additionally, complications and revision surgery have also been examined.

For athletes with an incompetent UCL, the DANE TJ reconstruction has been shown to have a solid biomechanical profile and excellent outcomes on par with other UCL reconstruction techniques. Additionally, it allows for anatomic reconstruction, and helps facilitate the easy of graft tensioning and graft fixation using familiar implants. Suspensory fixation is a relatively new technique that can offer another option for ulnar or humeral fixation with growing research that illustrates favorable biomechanical properties; however, additional research is necessary to elucidate its success in the clinical setting.

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