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Selection of Tendon Grafts for Distal Radioulnar Ligament Reconstruction and Report of a Modified Technique

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Abstract

Purpose—To investigate the graft length necessary to complete a distal radioulnar ligament reconstruction and assess the suitability of several tendon graft sources.

Methods—We measured the graft length needed to complete the distal radioulnar ligament reconstruction in 7 fresh-frozen cadaver specimens. The pure tendon lengths of 7 tendon graft sources were measured: palmaris longus, extensor indicis proprius, slips of extensor digiti minimi and abductor pollicis longus, and portions of flexor carpi ulnaris, flexor carpi radialis, and extensor carpi ulnaris. A modified technique which allows for a shorter length of graft is also described, and the suitability of each graft source for this technique was assessed.

Results—The mean graft length needed to complete the original and modified reconstructions were 138 mm and 89 mm, respectively. The average length of the tendon graft when measured as pure tendon were: palmaris longus (127 mm), slip of extensor digiti minimi (112 mm), extensor indicis proprius (100 mm), partial flexor carpi radialis (87 mm), slip of abductor pollicis longus (69 mm), partial flexor carpi ulnaris (67 mm), and partial extensor carpi ulnaris (67 mm). The palmaris longus was too short for the original technique in the majority of specimens but was sufficient to complete the modified technique in every specimen that had a palmaris longus. Six specimens also had an extensor indicis proprius of suitable length for the modified technique.

Discussion—The length of donor graft required for the modified reconstruction was significantly less than that needed for the original reconstruction. Three specimens had no donor tendons sufficiently long to complete the original technique if a pure tendon graft were used, whereas the modified technique could be completed in all specimens.

Clinical Relevance—Many tendon graft sources in the upper extremity are of insufficient length to complete the distal radioulnar ligament reconstruction as described. A modified technique using suture anchors may be a useful alternative in such cases.

Keywords

Distal Radioulnar Ligament; Distal Radioulnar Joint; Reconstruction; Tendon Graft; Cadaver

Introduction

Because of the minimally constrained architecture of the sigmoid notch, the surrounding soft tissues of the distal radioulnar joint (DRUJ) provide stability.(1,2) In cases of chronic DRUJ instability, distal radioulnar ligament (DRUL) reconstruction may be necessary when the components of the triangular fibrocartilage complex are beyond repair. A number of tendon graft-based reconstructions have been developed over the last 30 years, but most have been met with only limited success.(3) Adams and Berger have popularized a technique that replicates both orientation and function of the palmar and dorsal distal radioulnar ligaments.(4,6) In their reconstruction, a tendon graft is threaded through the distal radius via a dorsal-to-volar bone tunnel. Both graft ends are then passed through an oblique tunnel in the distal ulna, wrapped around the ulnar neck, and tied together as a half-hitch (Figure 1). This technique effectively recreates both the palmar and dorsal portions of the DRUL with a single graft, emulating the varying levels of tension provided by each throughout the pronation-supination arc.(5) The effectiveness of this reconstruction has been examined in 14 patients, with all patients reporting at least an 85% recovery of strength and motion. Stability was completely restored in 12 of the 14, which allowed for return to previous work, sports, and avocations without restrictions.(6)

The senior author (S.W.) has found this reconstruction useful and effective but has noted a technical limitation that has also been acknowledged by Adams et al.(7) We have encountered occasions in which the tendon graft length was too short to loop around the ulna, requiring us to use a suture anchor to secure the graft (Figure 1). In this cadaveric investigation, we sought to determine the length of graft needed to complete both the original and our modified technique for this DRUL reconstruction. Additionally we evaluated the length of alternative local tendon grafts because the palmaris longus is not consistently present.(8) We hypothesized that the majority of graft sources would not have sufficient length to perform the DRUL reconstruction as originally described and that a greater number of graft sources would be suitable for the modified technique.

Materials and Methods

Specimens

Seven fresh-frozen cadaveric upper limbs were thawed overnight and allowed to reach room temperature. Bone tunnels were created in the distal radius and ulna of each of the specimens, in accordance with the protocol described by Adams and Berger (Figure 1).(6) Seven tendons were harvested in each forearm, including the palmaris longus (PL)(when present), extensor indicis proprius (EIP), 1 slip of the abductor pollicis longus (APL), 1 slip of the extensor digiti minimi (EDM), and portions of flexor carpi ulnaris (FCU), flexor carpi radialis (FCR), and extensor carpi ulnaris (ECU) tendons. These tendons were chosen because they are expendable and are commonly used in reconstructions or tendon transfers.

Tendon Grafts

All tendon grafts were harvested with the use of an Acufex Closed Tendon Stripper (Smith & Nephew; Memphis, TN) with the specimens at room temperature and not desiccated. The distal end of the PL tendon was exposed by a transverse incision made 2 cm proximal to the distal wrist flexion crease, and the tendon was divided in the proximal palm at the point of the tendon's flare into its aponeurosis.(9,10) To extract the slip of EDM, the distal portion of the tendon was exposed by a transverse incision over the fifth metacarpophalangeal joint. (11) The ulnar slip was identified and separated from the extensor digitorum communis at a secondary incision just distal to the dorsal portion of the ulnar styloid. The EIP tendon was similarly harvested by isolating it from the extensor digitorum communis through a transverse incision over the second metacarpophalangeal joint and a transverse incision at the distal radius.(8) For both the EIP and EDM, the tendons were identified proximal to the extensor retinaculum and isolated from nearby tendons before a tendon stripper was used to free the tendon from its muscle.

For the portion of FCU, a transverse incision was made over the tendon near the wrist flexion crease. The tendon was divided into 2 equal portions, whereupon one was cut from its insertion on the pisiform. A tendon stripper was used to extend this division proximally, whereupon another transverse incision down to the level of the tendon was made parallel and 4.5 cm proximal to the first incision. The tendon slip was then withdrawn proximally through the second incision, and the remainder extracted with a tendon stripper via the second incision.(12)

The partial FCR tendon was also harvested by means of multiple small transverse incisions on the distal forearm. The tendon was initially exposed at the wrist and split in half longitudinally just proximal to the scaphoid tubercle. The portion was followed proximally with a tendon stripper, and multiple transverse incisions were made through which the tendon was removed and stripped until it was freed from its muscle.(13)

The partial ECU tendon was similarly divided at its insertion at the base of the fifth metacarpal via exposure through a transverse incision and stripped proximally with multiple incisions until a point at which it could be released from the muscle.(14)

To harvest the slip of APL, a transverse incision was made at the first dorsal compartment over the dorsum of the thumb. The extensor retinaculum was divided over the first extensor compartment, and a slip of the APL was isolated and followed distally to the base of the first metacarpal, where it was detached from the bone. The tendon was then stripped proximally until it was released from its muscle.(15)

The width of each tendon at the level of the musculotendinous junction was measured after harvest while keeping the specimens moist (Figure 2).(16) The measured length of the tendon consisted of the length as measured from the terminus of the musculotendinous junction to the distal point of transection.(8) This pure tendon length was chosen because it was a reproducible measurement with rather consistent cross-sectional uniformity.

Assessment of Length Requirements

A length of 3 mm umbilical tape was used to determine the length of tendon needed for the reconstruction procedure, both with and without wrap around the ulnar neck for each cadaveric specimen. A suture passer was inserted through the radial tunnel from dorsal-to-volar and 1 end of the umbilical tape was pulled through. A straight hemostat was passed over the ulna head proximal to the triangular fibrocartilage and pushed through the volar DRUJ capsule. The other end of the umbilical tape was grasped with the hemostat and pulled back along this track. Both ends of umbilical tape were then passed through the ulna tunnel via a suture passer to exit the ulna neck.

In order to approximate the length of tendon that would be necessary for both the original method and the modified procedure using suture anchors, 2 measurements were taken. First, the length of umbilical tape required to be flush with the surface of the ulnar neck upon exit from the tunnel was marked and named the anchor length. Then, the ends were wrapped in opposite directions around the ulnar neck with 1 tendon passing deep to the ECU sheath. With the forearm in neutral rotation and the DRUJ compressed, the tendon graft ends were pulled taut and tied together against the dorsum of the ulna. The length of tape necessary to reach the edge of the knot using the originally described technique was recorded as the wrap length.

Statistical Methods

All comparisons of continuous variables were assessed using independent 2-tailed, 2-sample t-test with α set to 0.05. All results are represented graphically and within the text as the mean $\pm$ standard deviation. Results with $P < 0.05$ were considered statistically significant.

Results

One of the 7 specimens tested did not have a PL. Otherwise, the full set of 7 tendons was harvested from each of the 7 specimens.

The average length of tendon required for the original reconstruction technique with wrap was 138 ± 36 mm. By comparison, 89 ± 20 mm was sufficient if a suture anchor were to be used, a statistically significant difference ($P = 0.011$). The pure tendon lengths of each of the candidate tendon grafts are presented in Table 1.

Overall, none of the candidate tendons for grafting had a mean pure tendon length equal to or greater than the mean length required for the original wrap technique.

For the modified technique, the PL, ulnar slip of EDM, and EIP tendons all had a mean tendon length sufficient for the mean length required for the modified procedure across all specimens. The other 4 tendons (APL, partial FCU, partial FCR, and partial ECU) had mean lengths that were less than the mean length for the modified technique.

In terms of sufficiency per individual specimen, in 3 of the 6 specimens that had a PL, it was sufficiently long to employ the original DRUL reconstruction technique. Two specimens also had ulnar EDM tendons longer than needed for the wrap length for those particular

specimens. No other tendons were sufficiently long in any of the individual specimens to perform the originally described reconstruction. Thus, in total, 5 of 48 tendons met the length requirement for the anatomic DRUL reconstruction for their individual specimen.

When the modified technique was similarly examined on a specimen-by-specimen basis, 6 of the 7 specimens had a PL long enough for the technique. Six specimens had an EIP that was long enough for the anchor technique. Four specimens each demonstrated a sufficiently long slip of EDM and partial FCR. Two specimens had a portion of ECU that was long enough, one had a sufficiently long slip of FCU, and none of the APL tendons were long enough. In total, 23 of the 48 tendons harvested were long enough for the anchor technique.

All of the tendons tested were significantly wider than the palmaris longus (4.1 ± 0.9 mm), except for the EIP (4.0 ± 0.8 mm) and slip of EDM (3.0 ± 0.8 mm). Of these, the EDM was significantly narrower than the palmaris longus ($P=0.044$), leaving the EIP and portion of ECU as the only tendons with widths comparable to the PL.

Discussion

The mean length of tendon graft required to complete the modified anatomic DRUL reconstruction was significantly less than that required for the originally described technique. This difference may be clinically meaningful as well, since only 10% of all available tendon grafts when harvested as a pure tendon were of sufficient length to complete the original technique, versus 48% of the tendon grafts sufficient for the modified technique.

As hypothesized, a substantial portion of the specimens tested did not have tendon graft sources with sufficient pure tendon length for the original anatomic DRUL reconstruction. Two of the specimens only had a PL adequate for the original technique, another had a slip of EDM of sufficient length, and a fourth specimen had both. Consequently, for the remaining 3 specimens tested, the originally described DRUL reconstruction could not be correctly performed with any of the 7 donor tendons that were tested. The PL was thus an appropriate choice of graft in the original description, as it was longer than the other tendons tested; yet it was sufficient for only 3 of the 7 specimens measured.

We chose to measure the pure tendon length as opposed to potential available tendon length which would include intramuscular portions of tendon. This measurement was chosen because it is a reproducible measurement, requires less preparation time, and is rather uniform. There are a number of alternatives available where the reconstruction cannot be performed with pure tendon alone: resort to a lower extremity graft, use intramuscular portions of tendon, or use alternative fixation methods such as the one described here.

With the modified technique involving suture anchors, 3 of 7 tendons tested exceeded the mean length of tendon required. Of these 3 tendons, the PL and EIP were sufficient for the modified technique in 6 of 7 specimens. The EIP was also similar in width to the PL. The EDM was adequate in 5 of 7 specimens tested, but was considerably narrower than the PL. These 2 tendons may thus represent reasonable alternatives to the PL when choosing the modified technique. No data exist, however, on the minimum width of the tendon graft. Care

should be taken when using a thin tendon graft for a reconstruction that likely has to resist intermittent high loads.

An important characteristic of the modified technique was that every specimen studied had at least 1 tendon graft source that could be used to complete the modified DRUL reconstruction, in contrast with a roughly 40% chance that none of the tested tendons in the ipsilateral upper extremity would be available to perform the original technique. The use of a suture anchor simplifies the technique, shortens operative time, and minimizes the technical difficulty of tying a secure knot between 2 short tendon ends. A theoretical benefit of avoiding a tendon loop around the ulna is preventing bony erosion underneath the loop, as can occur with the phalanx in flexor pulley reconstructions.(18)

The limitations of this study include its small sample size, which may not yield accurate prevalence data for the PL and other tendons. Other investigators, however, have demonstrated a comparable prevalence of the PL in large studies across different populations.(19) Despite our limited specimen number, we were able to demonstrate statistically significant differences between techniques and graft sources. Some of the tendons investigated in this study also exhibited a high degree of variability among specimens, though this should not affect our primary outcome of suitability for autograft in each individual specimen. Future work will be necessary to determine the biomechanical requirements of the reconstruction, and whether suture anchors are sufficient to restore distal radioulnar joint stability. Biomechanical testing to determine whether each of the tendons tested would be able to withstand the tensile loads experienced as a result of their use in this reconstruction would be informative as well. The decision to measure pure tendon length may be controversial as well, since some surgeons may elect to extend the length of tendon by stripping tendon grafts well into the intramuscular portion. The modified technique presented here represents an alternative in which the use of intramuscular tendon, which may be of inconsistent length and mechanical strength, is avoided. Furthermore, while potential available tendon length is often greater than the pure tendon length, opinions may differ on how much of the intramuscular portion is usable. Finally, umbilical tape was used as a surrogate to measure length. While this method may have limited the precision of the measurements, we felt this to be preferable to record a single uniform measurement with which to compare lengths, rather than introducing multiple sources of error by repeating reconstructions serially.

Some surgeons may choose to use umbilical tape to obtain a preliminary estimate of the needed graft length before choosing the graft. By first preparing the DRUJ for reconstruction and using umbilical tape to measure the length of graft, the surgeon could obtain a reasonable estimate of the length of graft needed for either the original or modified technique. If the anticipated donor tendon is found to be of insufficient length (on the basis of normative data), a number of options are available. The surgeon may choose to use a modified technique using suture anchors as described here (with no published data yet regarding its outcomes), use the full tendon length including the intramuscular portion, or select a tendon from the lower extremity predicted to be of sufficient length. Future investigations will be necessary to examine the clinical outcomes in patients treated using this technique.

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Figure 1. Original and Modified Distal Radioulnar Ligament Reconstruction Procedures
Illustration of the tendon graft reconstruction through bone tunnels in the distal radius and ulna. (A) Posteroanterior view of the reconstruction technique, demonstrating the original wrap technique in which the tendon graft is passed around the ulnar neck before the ends are tied. (B) View of the anchor technique in which the ends of the tendon graft are secured to the shaft of the ulna with the use of a suture anchor.

Figure 2. Technique for Measurement of Tendon Graft Length and Width

Representative image of a tendon graft. The tendon length was defined as the length of tendon that is free from surrounding muscle, from the musculotendinous junction proximally to the point of transection distally. The width of each tendon graft was defined as the musculotendinous (MT) width, which consisted of the width of tendon measured at the musculotendinous junction. Both measurements were taken while the specimens remained naturally moist.

Table 1

Average Lengths of Tendon Grafts and Average Reconstruction Length Requirements

Measurement	Average Length	% Specimens Sufficient for Original Technique	% Specimens Sufficient for Modified Technique
Palmaris Longus	127 ± 20 mm	43%	86%
Extensor Indicis Proprius	100 ± 25 mm	0%	86%
Slip of Extensor Digiti Minimi	112 ± 23 mm	29%	57%
Portion of Flexor Carpi Radialis	87 ± 16 mm	0%	57%
Portion of Extensor Carpi Ulnaris	67 ± 22 mm	0%	29%
Portion of Flexor Carpi Ulnaris	67 ± 17 mm	0%	14%
Slip of Abductor Pollicis Longus	69 ± 18 mm	0%	0%
DRUL Reconstruction (Original)	138 ± 36 mm	--	--
DRUL Reconstruction (Modified)	89 ± 20 mm	--	--

Average lengths, across all specimens (n=7), in comparison with the length requirements for both the original and modified DRUL reconstructions. Also presented are the percentages of each tendon that were of sufficient length for the original and modified techniques for their individual specimen. Data are presented as mean ± standard deviation. DRUL = distal radioulnar ligament.