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Functional Outcome of Extensor Carpi Radialis Longus Transfer for Finger Flexion in Posttraumatic Flexor Muscle Loss

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Purpose: The purpose of this study was to assess the functional outcome after extensor carpi radialis longus (ECRL) transfer for restoration of finger flexion in patients with flexor muscle loss after direct trauma.

Methods: We evaluated 8 patients who had ECRL transfer between 1995 and 2003. Flexion gained was assessed by measuring the digit-to-palm distance (DPD). The grip strength was compared with that of the opposite normal limb. The average follow-up period was 41 months. We compared the results obtained with other modalities of restoration of finger flexion, namely a pedicled latissimus dorsi muscle transfer or a free functioning muscle transfer (FFMT) using the series available in the literature.

Results: Four patients had a good result with a DPD of 0 cm in all fingers and an average grip strength of 65% of the opposite hand. Two patients had an average result with a DPD of 1.5, 2, 1.7, and 1.5 cm for the index, middle, ring, and small fingers, respectively, and an average grip strength of 58%; 2 patients had a poor result with a DPD of 5.0, 5.5, 5.0, and 3.0 cm for the index, middle, ring, and small fingers, respectively, and with an average grip strength of 21% of the opposite hand.

Conclusions: The ECRL transfer yields good results if the intrinsic muscles of the hand are functioning, the extensor compartment is uninjured, and the lower third of the forearm where the tendon junction is performed is relatively unscarred. In such instances the range of movement and grip strength achieved are better than a latissimus dorsi muscle pedicle graft and are comparable with a FFMT. This is achieved earlier than the time taken for reinnervation of FFMT and without the attendant risks for flap failure. The ECRL transfer for finger flexor restoration is a more simple alternative that should be considered when possible. (*J Hand Surg* 2005;30A:267-272. Copyright © 2005 by the American Society for Surgery of the Hand.)

Key words: ECRL tendon transfer, finger flexor loss.

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Complete flexor compartment muscle loss can occur after direct muscle trauma, tumor excision secondary to Volkmann's ischemic contracture (VIC), or irreparable combined high ulnar and median nerve injuries. Reconstruction of finger flexors can be performed by either transfer of the extensor carpi radialis longus (ECRL) to the flexor digitorum profundus (FDP),¹⁻⁴ a latissimus dorsi muscle pedicle graft,⁵⁻⁷ or a free functioning muscle transfer (FFMT).⁸⁻¹²

ECRL tendon transfer and transfer of the latissimus dorsi (LD) were the earlier solutions used, particularly for VIC and combined median and ulnar nerve injuries.

Table 1. Patient Details

Patient	Age, y	Gender	Involved Limb	Mode of Injury	Associated Injuries	Period Between Injury and Tendon Transfer (mo)	No. of Surgical Procedures	Follow-Up Period After ECRL Transfer (mo)
1	25	M	Right	RTA	Brachial artery avulsion	4	4	96
2	24	M	Right	RTA	Fracture lateral condyle of humerus	0	1	48
3	27	M	Right	RTA	Segmental loss of median nerve, ulnar artery injury, and carpal dissociation	6	3	74
4	20	M	Left	RTA	Ulnar artery injury	5	2	36
5	27	M	Right	RTA	None	3	3	36
6	14	M	Right	RTA	Median nerve and radial artery injury	10	9	12
7	26	M	Left	Industrial accident	Fractured both bones of forearm	8	2	12
8	51	M	Right	RTA	Injury to ulnar neurovascular bundle	10	3	12

RTA, road traffic accident.

Transfer of the ECRL is simple but depends on intact radial nerve and extensor compartment. LD transfer has the advantage that it is possible to perform irrespective of the damage in the arm and the forearm but has the disadvantage of being a major procedure. The LD muscle has to be dissected to the level of its attachment to the iliac crest where the blood supply may be tenuous and hence needs a good skin cover at the level of its attachment to the flexor tendons. More recent reports use FFMT. It requires microsurgical expertise and a good motor nerve in the vicinity for innervation and starts functioning after a lag period.

Earlier reports detailing the technique of the ECRL to the FDP¹⁻⁴ are based on the work on VIC and combined median and ulnar nerve injuries. We present a series of 8 patients with traumatic flexor compartment muscle loss with relatively long-term follow-up evaluation in whom ECRL transfer has been used for finger flexion. Such injuries usually are associated with overlying skin loss. FFMT and LD muscle pedicle graft appear to be good solutions to provide both cover and function. The available literature is insufficient to compare the long-term outcome of these procedures with staged reconstruction procedures such as ECRL transfer to the FDP. There is no definite way to assess the functional outcome of this tendon transfer and we are proposing a system that is based on the digit-to-palm distance (DPD) achieved.

Patients and Methods

Eight male patients between the ages of 14 and 51 years (average age, 28 y) had ECRL transfer for the reconstruction of finger flexors in the period between 1995 and 2003. All 8 patients had loss of the flexor compartment muscles secondary to direct trauma. The injury involved the dominant upper limb in 6 of 8 patients. Two patients had associated injury to the median nerve and 1 had injury to the ulnar nerve. One patient had a critical vascular injury that necessitated brachial artery repair whereas 4 patients had noncritical vascular injuries. Patients had an average of 3.4 surgical procedures (range, 1–9 procedures). Patient details, cause of flexor muscle loss, nature of associated injuries, period between injury and tendon transfer, number of surgical procedures performed, and follow-up period are summarized in Table 1. All patients had ECRL transfer to the FDP flexors at an average of 5.8 months (range, 0–10 mo) from injury. Two patients had loss of flexor pollicis longus (FPL). In 1 patient ECRL was used to motor the FPL (patient 7) whereas in the other the brachioradialis was used (patient 6).

Surgical Technique

The ECRL is detached from its insertion at the base of the second metacarpal and is dissected free up to the middle of the forearm through multiple incisions. It then is withdrawn proximally and redirected subcutaneously along the radial border of the forearm to the

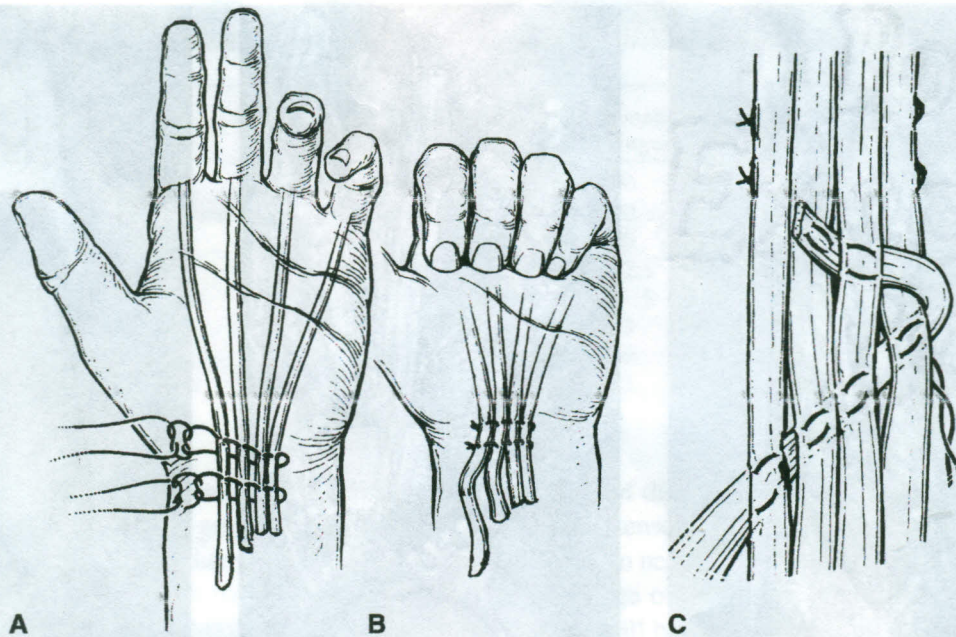


Figure 1. Technique of tendon transfer. (A, B) FDP tendons are plicated to produce normal cascade of the fingers. (C) Technique of weaving the ECRL tendon into the plicated FDP tendon.

volar side of the wrist and sutured to the FDP tendons. The recipient FDP tendons are prepared by plicating them together in an appropriate tension to achieve a normal cascade of the fingers (Figs. 1A, 1B). The ECRL tendon then is woven into the prepared FDP tendon by passing it through each slip of the FDP in an oblique manner and is sutured with 3-0 nonabsorbable sutures (Fig. 1C). The wrist is kept in a neutral position with the tension adjusted so that the fingers are in a semiflexed position and the ECRL is in full tension. None of the patients had any secondary procedure for improving function.

Physiotherapy Protocol

The plaster cast is removed 4 weeks after the procedure to start therapy. In the first week the patient is advised to extend the wrist, simultaneously flexing the fingers. In the second week active extension of the fingers at the metacarpophalangeal joint is allowed. In the third week active wrist movements are encouraged. Gentle straightening exercises are allowed; if there is evidence of flexor tightness then gentle stretching exercises are performed. Patients are seen every week. At this stage patients are advised not to lift or carry heavy weights. Activities of daily living are started from the eighth to the tenth week. Patients usually start their normal activities by 3 months.

Evaluation Technique

The functional outcome of these patients was analyzed by our occupational therapists. It was noted that the activity levels and patient satisfaction paralleled the extent the patients could make a fist. Hence DPD was used to classify the results. If a patient reached full flexion (0 cm DPD) then the result was classified as good, up to 2 cm of DPD was classified as average, and greater than 2 cm of DPD was considered poor.

Although the DPD represents the size of the object that could be held the usefulness of the range of movement gained will depend on the grip strength. The grip strength was measured with a dynamometer (Jamar; Padgett Instruments, Kansas City, MO). This was compared with the grip strength of the opposite hand and expressed as a percentage. The grip strength gained was compared with series available in the literature in which other techniques had been used for flexor muscle replacement. Grip strength was not used in classifying the result because it was possible to record a good grip strength without making a full fist.

Results

Patients were followed up for an average period of 41 months (range, 12–96 months). Four patients (patients 1–3, 7) had a good result with a DPD of 0 cm in all fingers and an average grip strength of 65% of the opposite hand (Figs. 2A–2F). Two patients (patients 4, 5) had an average result with a DPD of 1.5, 2.0, 1.7, and

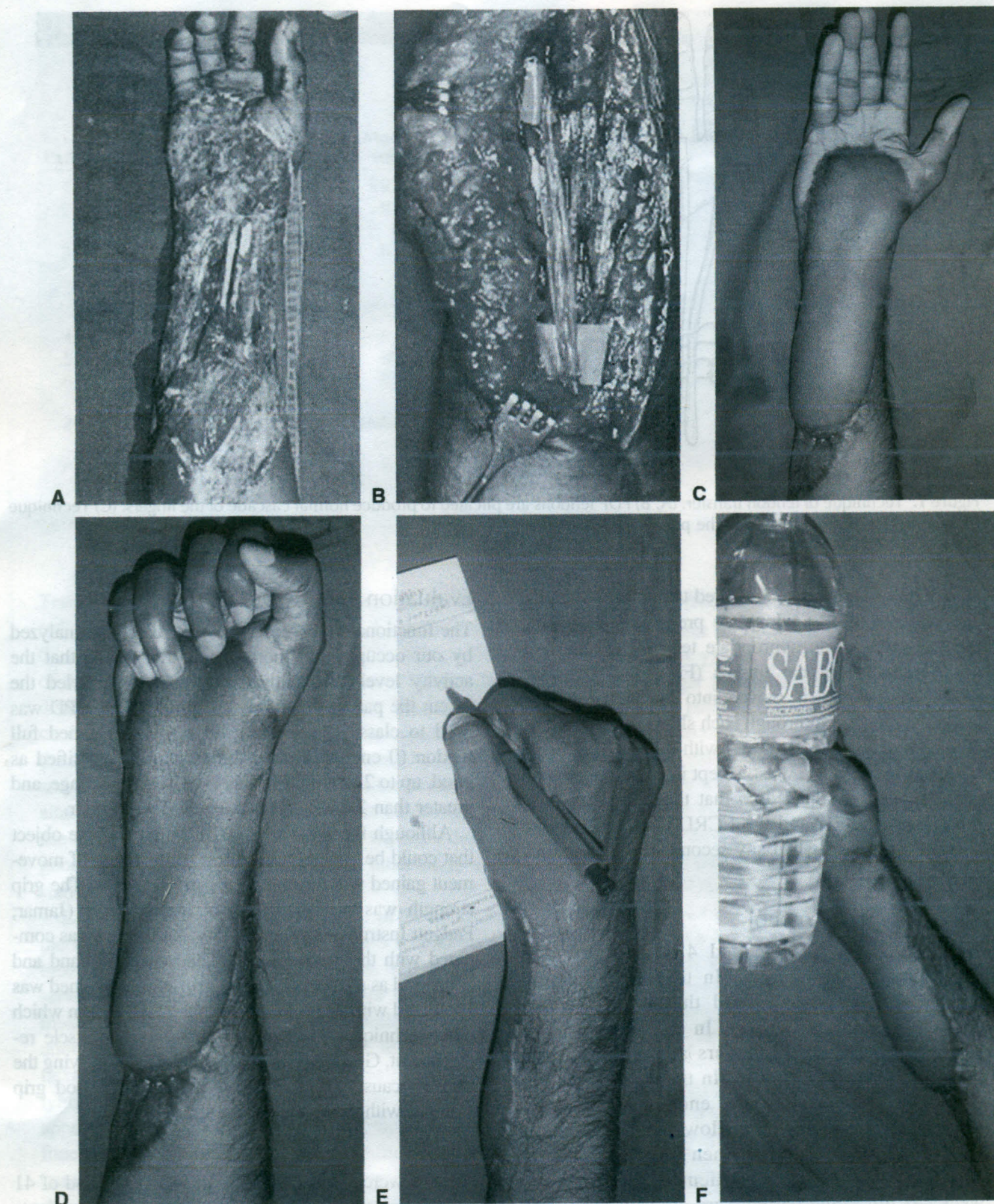


Figure 2. Patient 3. (A) Postdebridement appearance of the wound showing the soft-tissue defect. Note the intact flexor carpi radialis and FPL. (B) Median nerve grafting performed beneath the abdominal flap 4 months after injury. (C, D) Range of movement 6 years after ECRL transfer. (E, F) Functional activity after transfer. Classified as a good result.

Table 2. Results of ECRL Transfer

Patient	DPD (cm)				Grip Strength (kg)	
	Index Finger	Middle Finger	Ring Finger	Small Finger	Injured (kg)	Percentage of Uninjured
1	0	0	0	0	24	63
2	0	0	0	0	25	83
3	0	0	0	0	20	50
4	2.5	3	2.5	2.5	20	44
5	1	1	1	.5	25	71
6	5	5	5	3	5	25
7	0	0	0	0	25	63
8	5	6	5	3	5	18

1.5 cm for the index, middle, ring, and small fingers, respectively, and an average grip strength of 58%, whereas 2 patients (cases 6, 8) had a poor result with a DPD of 5.0, 5.5, 5.0, and 3 cm for the index, middle, ring, and small fingers, respectively, and a grip strength of 21% of the opposite hand. Taken as a whole the average DPD measured 1.7, 1.9, 1.7, and 1.1 cm for the index, middle, ring, and small fingers, respectively, and patients achieved 52% of the grip strength of the opposite normal hand (range, 18%–83%). All patients passively could get to 0 cm DPD and the results given represent the flexion lag. The DPD and grip strength gained are shown in Table 2.

Of the 4 good results 3 did not have any nerve injuries, whereas 1 had segmental loss of median nerve that was bridged by sural nerve grafts. In this patient the result may be good because the ulnar nerve was intact and a major portion of the intrinsic function was retained. There was correlation between regular physiotherapy and a successful outcome. Patients who attended physiotherapy daily achieved good range of movement. None of the patients who were irregular with therapy achieved good movement.

Discussion

Three options are available for replacement of loss of flexor muscles in the forearm. The first is a transfer of the ECRL tendon to FDP,^{1–4} the second is an extended pedicle latissimus muscle flap,^{5–7} and the third is a free muscle transfer.^{8–12}

If the extensor musculature of the forearm is intact then transfer of the ECRL may be the preferred procedure because it is quicker and simpler and provides good functional recovery in a shorter time.¹¹ Wrist extensors are synergistic muscles to finger flexors and are easy to re-educate. The ECRL transfer for finger flexion requires full wrist motion because there is no wrist extensor muscle with adequate amplitude for full

flexion of digits.^{3,13} The amplitude of excursion of the wrist extensors is 3 to 4 cm whereas the amplitude of excursion needed for full finger flexion is about 7 cm.¹⁴ The range of movement after transfer of the wrist extensor will be supplemented by the additional range of approximately 2.5 to 3.0 cm, contributed by extension of the wrist. The sum of these 2 effects will give adequate total range of movement. When transferring such a muscle with a difference in excursion length the tension adjustment during tendon transfer is important.

A good range of movement was achieved in the patient in whom ECRL was used to power both the finger flexors and the FPL (patient 7). The thumb and fingers closed at the same time, however, and the patient found it inconvenient functionally. This could be avoided by using another motor for the FPL. The brachioradialis would be a good choice if it is uninvolved. We have performed this for 1 patient (patient 6). There is independent thumb movement but the stiffness from other problems precludes a good result.

Two patients had approximately 40° of flexion contracture at the metacarpophalangeal joint at the time of tendon transfer (patients 6, 8). The interphalangeal joints had nearly full passive range of motion. We perceived that they had reached a plateau stage in physiotherapy and performed the tendon transfers. In both instances the outcome was in the poor category. Although this poor result cannot be ascribed fully to the presurgical stiffness (patient 6 had flap complications and median nerve injury, patient 8 had comorbid factors such as heart disease and was noncompliant with therapy) it is better to have full passive range of motion before performing the tendon transfer.

Patients with VIC for whom we have performed the same surgery achieved an inferior result when compared with patients with trauma. In addition to flexor compartment loss patients with VIC suffer

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Patients with VIC for whom we have performed the same surgery achieved an inferior result when compared with patients with trauma. In addition to flexor compartment loss patients with VIC suffer

from nerve injury and the bed for transfer also is not optimum. In most patients with severe VIC there is involvement of the extensor compartment to a variable extent and it would be rare to find a patient with grade V power in the wrist extensors.

An attempt was made to assess the relative value of this technique with other options by comparing them with established series. Ihara et al⁶ published their experience with pedicled LD transfer in 6 patients for the restoration of finger flexion. The total active motion varied from 30° to 170° (average, 82°) in 5 patients, although there was no movement in 1 patient owing to severe contracture of the finger joints. A study of the grip strength showed that 2 patients achieved a power grip of more than 10 kg, although 4 patients achieved a power grip of less than 3 kg. Gousheh et al⁷ in their report of 28 cases of pedicled LD transfers for restoring finger flexion achieved a mean flexion of 38° at the metacarpophalangeal joint, 85° at the proximal interphalangeal joint, and 30° at the distal interphalangeal joint. Hand strength measurements were not performed in their study.

Favero et al⁸ reported the Mayo Clinic experience in 5 patients for whom FFMT was performed to restore finger flexion using the LD muscle. On average the DPD was 2.0, 2.1, 2.3, and 1.4 for the index, middle, ring, and small fingers, respectively. The mean grip strength was 31% of the opposite hand and all had a minimum of 1 session of tenolysis to improve the range of movement.⁶ Manktelow et al¹² presented their long-term experience with the free functioning gracilis muscle transfer in 12 patients for the replacement of finger flexors. Of their 12 patients 1 was a complete failure and 9 achieved a full range of movement. The maximum grip strength obtained with this procedure was 50% of normal grip strength.

We believe that the results of the ECRL tendon transfer are excellent if performed for localized trauma of the forearm with good intact extensors, an intact median and ulnar nerve, and good supple skin cover along the route of transfer. The pedicled LD muscle flap can reach the middle of the forearm and the distal tendon ends must be available at that level for attachment. A pedicled LD transfer does not achieve full finger flexion and the resulting grip strength is considerably less than a good tendon transfer. An advantage ECRL transfer has over the free functional muscle transfers is that microsurgical

skills are not essential, there are no chances of a complete failure, and it does not depend on nerve regeneration for reinnervation. Although both free gracilis muscle transfer and ECRL tendon transfer achieve comparable range of movement and grip strength this result is achieved much earlier in a tendon transfer than with a FFMT.

The transfer of the ECRL tendon for reconstruction for flexion in patients with posttraumatic loss of flexor compartment muscles is a good option. Regular supervised physiotherapy for at least 4 to 6 weeks after the immobilization period is essential to achieve good function.

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