

## Original Article

# Brachioradialis to flexor digitorum profundus tendon transfer to restore finger flexion

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### ABSTRACT

**Introduction:** The main deformity following an adult lower brachial plexus injury is the loss of finger flexion. Distal nerve transfers have been used to restore finger and thumb flexion followed by tendon transfers for intrinsic replacement for opening of the fingers. When patients present beyond 6 months, only tendon transfers are applicable. Since the brachioradialis (BR) is always spared in such injuries, it is the ideal muscle to provide finger flexion. Wrist extensor power may not be normal for the use of the radial wrist extensor to serve as donor. BR to FDP transfer provides reasonable flexion range and an acceptable hand function to permit activities of daily living, when associated with ancillary procedures like opponensplasty, PIPJ arthrodesis. **Materials and Methods:** Eleven patients underwent a BR to FDP tendon transfer between January 2013 and January 2017 of which eight patients came for follow-up. **Results:** Four of the eight patients got a functionally useful hand to carry out activities of daily living with hook grip, span grasp, key pinch, chuck grip and pulp pinch. These patients also underwent simultaneous or secondary ancillary procedures. Four of the patients need secondary procedures to further improve functionality of the hand inspite of having a flexion range. **Conclusion:** The BR is an effective donor in providing adequate range and power of finger flexion in lower plexus injuries.

### KEY WORDS

Brachial plexus injury; brachioradialis; finger flexion; flexor digitorum profundus; tendon transfer

### INTRODUCTION

Loss of finger flexion can result from the lower type of brachial plexus paralysis, combined high injuries of median and ulnar nerves and rarely loss of forearm

muscles.<sup>[1]</sup> Avulsion of C7–T1 or C8 and T1 roots is a rare entity in adult brachial plexus lesions representing 3% of all brachial plexus injury (BPI), where spontaneous recovery is not possible. Residual paralysis involving C7, C8 and T1 nerve roots with incomplete recovery of C5 and C6 or C5–C7 is not common in pan brachial plexus

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injuries; however, there are chances of useful recovery of elbow extension, wrist extension and wrist flexion. There seems to be a deficit in the recovery of finger flexion in almost all of the cases.

In such injuries, in addition to loss of the flexor digitorum profundus (FDP), there is an accompanying loss of the flexor pollicis longus (FPL) and varied loss of the function of intrinsic along with absence of finger extension due to associated paralysis of extrinsic extensors. Even with a successful nerve repair, secondary tendon transfers are required to address the intrinsic paralysis.<sup>[2]</sup> The clinical presentation is a flat hand and thumb that is adducted because of gravity; all grip functions is lost [Figures 1 and 2].

Although nerve repairs below the elbow can return the function of the FDP, higher injuries, especially when treated with nerve grafts, may not give adequate return of function.<sup>[3]</sup> In early presentation of lower plexus injuries, finger flexion and finger extension can be restored by using peripheral nerve transfers like BR motor branch or brachialis branch of the musculocutaneous nerve to anterior interosseus nerve, and supinator branch to posterior interosseus nerve.<sup>[5-7]</sup>

The functioning muscle transfer is a well-known procedure, especially for pan brachial plexus injuries and electrical burns, where no local muscles are available for a transfer. This procedure has a 6–12 month rehabilitation period before any useful recovery can be seen.<sup>[8]</sup> Tendon transfers, in contrast, provide an earlier return of function, within a period of 3 months.

This study analyses the functional improvement in finger flexion following transfer of the BR muscle to the FDP tendon.

### Aims and objective

The aim and objective of this study is to determine the efficacy of the BR transfer in providing finger flexion and the quality of hand function regained after other ancillary procedures on the thumb and fingers.



Figure 1: Preoperative image showing flat hand

## MATERIALS AND METHODS

Eleven patients underwent BR to FDP tendon transfer between January 2013 and January 2017. All of them were diagnosed with lower BPI; the time to presentation for treatment from the time of injury varied from 10 to 30 months.

All the patients had a flat hand with an inability to flex the fingers at the proximal interphalangeal joint (PIPJ) and distal interphalangeal joint. In addition, these patients had evidence of intrinsic muscle paralysis and loss of finger extension.

A complete physical examination was performed to assess the strength of all available muscles in the upper limb at or below the elbow. Among the 11 patients, nine were male, and two were female. Age ranged from 20 to 45 years, and there was one child with 6 years of age.

All these patients had a normal shoulder function; elbow extension was M3 to M4 in 5 patients due to C7 injury. Two of the 11 patients had a normal wrist extension.

Details of these are mentioned in Table 1.

The primary surgical procedure performed was a transfer of the BR tendon to the FDP tendon.

Additional procedures were performed either simultaneously or sequentially to address the problems of

- Absent FPL function of thumb
- Absent palmar abduction of thumb
- Intrinsic paralysis and 'claw attitude' at the PIPJ of the fingers.



Figure 2: Preoperative image with flat hand and adducted thumb

Details of these are mentioned in Table 2.

At the 6 months follow-up examination, patients were evaluated for range and strength of finger flexion achieved and ability to adopt various basic handgrips.

- a. Range of finger flexion was assessed by measuring distance between pulp of the index finger and distal palmar crease with a scale
- b. Strength of finger flexion was assessed by passively stretching the fingers completely by examiner's hand and noted per Medical Research Council (MRC) grades
- c. Hook grip strength was assessed by measuring maximum weight the patients can hook (500 ml normal saline pints in a plastic bag) with elbow in extension.

Patients were asked to perform various activities required to adopt various handgrips such as holding a pin, key, wooden block, glass, and recap a water bottle.

**Surgical technique**

The surgical procedure was performed under general anaesthesia or axillary brachial block with the application of an arm tourniquet inflated after exsanguination with an Esmarch's bandage.

A longitudinal incision was given over the middle two-fourths of the forearm along the medial border of the BR musculotendinous unit. The dissection of the tendon was started distally by carefully protecting the

**Table 1: Patient details**

Age/sex	DOI	Mode of injury	Type of injury	Time since injury (month)	Clinical presentation	
					Finger movement	Wrist movement
24/male	6 <sup>th</sup> May, 2015	Fall on conveyer belt	C7, C8, T1	11	FI and ext 0/5	FI+ Ext-
25/male	16 <sup>th</sup> April, 2015	RTA	C8, T1	16	FI and ext 0/5	FI 3+ Ext 4+
20/male	10 <sup>th</sup> February, 2012	RTA	C8, T1	30	FI and ext 0/5	FI 3+ Ext 4+
28/male	10 <sup>th</sup> July, 2012	Fall from height	C7, C8, T1	11	FI and ext 0/5	FI 3+ Ext -
20/male	21 <sup>st</sup> August 2015	RTA	C7, C8, T1	10	FI and ext 0/5	FI 3+ Ext 2+
6/female	10 <sup>th</sup> October, 2015	RTA	C8, T1	11	FI and ext 0/5	FI 3+ Ext 2+
24/male	27 <sup>th</sup> June, 2015	Fall from height	C8, T1	12	FI and ext 0/5	FI 3+ Ext -
40/female	27 <sup>th</sup> February, 2013	RTA	C7, C8, T1	10	FI and ext 0/5	FI 0 Ext 3+
19/male	02 <sup>nd</sup> January, 2013	RTA	C8, T1	27	FI and ext 0/5	FI 4+ Ext -
26/male	16 <sup>th</sup> April, 2012	RTA	C7, C8, T1	11	FI and ext 0/5	FI 0+ Ext 2+
45/male	25 <sup>th</sup> December, 2013	Assault	C8, T1	19	FI and ext 0/5	FI 0+ Ext 4+

Date of Issuance

**Table 2: Surgical procedures performed**

Primary surgical procedure	Complications	Simultaneous ancillary procedures	Secondary ancillary procedures
BR to FDP tendon transfer	Nil	C7 neurolysis	PIPJ, CMCJ arthrodesis
BR to FDP tendon transfer	Nil	FCR-APB	Intrinsic transfer using ECRB
BR to FDP tendon transfer	Nil	PL-APB	Intrinsic transfer, PIPJ arthrodesis
BR to FDP tendon transfer	Nil	FCR-APB	-
BR to FDP tendon transfer	Nil	CMCJ arthrodesis	-
BR to FDP tendon transfer	Nil	PL-APB	-
BR to FDP tendon transfer	Snapped tendon repair	-	PIPJ, CMCJ arthrodesis
BR to FDP tendon transfer	Nil	-	Brachialis to APB transfer, intrinsic transfer
BR to FDP tendon transfer	Nil	FCR-APB	-
BR to FDP tendon transfer	Nil	-	-
BR to FDP tendon transfer	Nil	CMCJ arthrodesis	-

BR: Brachioradialis, FDP: Flexor digitorum profundus, FCR: Flexor carpi radialis, PL: Pollicis longus, APB: Abductor pollicis brevis, ECRB: Extensor carpi radialis brevis, PIPJ: Proximal interphalangeal joint, CMCJ: Carpometacarpal joint

radial vessels on medial aspect as well as the radial nerve and the extensor muscles of the forearm on the lateral aspect. The distal insertion of BR was detached from the base of the radial styloid. Proximal dissection of the muscle was stopped at the widest part of the muscle in the proximal third of the forearm; however, the investing fascia was opened over the portion of the muscle below the elbow to improve excursion [Figure 3].

At least, 30 mm of passive excursion of BR tendon was obtained from resting position of the muscle.

The original incision was extended transversely over distal forearm or a second vertical incision was given along the ulnar aspect of the distal forearm to isolate the FDP tendons.

FDP tendons were identified, separated from the ulnar neurovascular bundle, cut at musculotendinous junctions and sutured together.

BR tendon was sutured to bunched up FDP tendons with 2.0 polypropylene suture using the Pulvertaft technique [Figure 4].

Tension of transfer was adjusted with elbow at neutral, forearm supine, wrist in neutral to allow all fingers to assume a hook position. A tube drain was placed after deflation of the tourniquet and the incision was closed in layers.

An above elbow dorsal blocking plaster slab was applied for immobilisation with the elbow flexed at 90°.

The patient was discharged between three to 5 days and was advised a follow-up visit after 1 week. The above elbow slab was converted to a below elbow slab after 3 weeks and finally removed at 6 weeks.



**Figure 3:** Intraoperative photograph showing isolated brachioradialis, flexor digitorum profundus, flexor carpi radialis, flexor pollicis longus

For the first 3 weeks, the patient performed isometric exercises using the BR to FDP transfer; next 3 weeks active flexion was done for 15 min four times a day. At 6 weeks, a dorsal outrigger splint was given to permit full active flexion of the fingers (as the opening of the hand was not possible due to lack of intrinsics and finger extensors).

## RESULTS

Eleven patients with complete loss of finger flexion and intrinsic paralysis were included in the study.

There were nine male and two female patients. Age ranged from six to 45 years mean age was 25.1. There was one female child, 6 years of age, while the age of other patients varied from 20 to 45 years.

All the patients presented for examination between 10 and 30 months after injury.

Five patients had Grade 3–4 elbow extension with C7, C8, T1 BPI and six patients had C8, T1 BPI. Only two of 11 patients had Grade 5 wrist extension. Pre-operative finger movements were nil in all the patients.

Primary surgical procedure to restore finger flexion was a tendon transfer using the BR end-to-end to the FDP of the fingers. Simultaneous ancillary procedures were performed in seven of the 11 patients addressing the thumb [Table 2]. The palmaris longus or flexor carpi radialis was transferred to abductor pollicis brevis (APB) in five patients. First, carpometacarpal joint (CMCJ) arthrodesis was done in 2 patients positioning the thumb in opposition, where no tendons were available for transfer. Five patients underwent secondary procedures, two had their PIPJ and CMCJ arthrodesis performed while intrinsic transfer using extensor carpi radialis brevis (ECRB) was performed on two patients. Brachialis to APB transfer was done in one patient; however, acceptable result was not achieved. One patient had



**Figure 4:** Brachioradialis flexor digitorum profundus, flexor carpi radialis-flexor pollicis longus tendon transfer

post-operative complication of snapped tendon repair after 2 weeks which was repaired immediately.

Three out of the 11 cases were not available for follow-up. The remaining eight cases have been evaluated on follow-up for pulp to palmar crease distance, strength of finger flexion, hook grip strength, total range of movement and ability to adopt basic hand grips and variables have been mentioned in Table 3.

Pulp to palm distance was 1 cm in one patient, 1–3 cm in six patients and 4 cm in 1 patient [Figures 5 and 6].

Finger flexion strength as assessed by examiners hand (after the complete extension of the fingers)



Figure 5: Postoperative finger flexion

was M4 in 5 patients and M3 in three patients [Figure 7 and Videos 1,2].

Hook grip strength was >4 kg in four patients and 2–4 kg in four patients [Figures 8 and 9].

Total ROM of fingers was 270° in one patient and 180°–240° in seven patients.

Four of the eight patients got a functionally useful hand to carry out activities of daily living with hook grip, span grasp, key pinch, chuck grip and pulp pinch. These



Figure 6: Pulp to palm distance 0 cm



Figure 7: Measuring strength of finger flexion



Figure 8: Measuring hook grip strength

Table 3: Results

<i>Pulp to palmar crease distance</i>	<i>Strength of finger flexion</i>	<i>Hook grip strength</i>	<i>Grips able to do</i>	<i>Total ROM</i>
0 cm	M4	>5 kg	Hook, span, key, chuck, pulp pinch	270°
2 cm	M4	>4 kg	Hook, span, key, chuck	240°
3 cm	M4	>4 kg	Hook, span, key, chuck, pulp pinch	210°
2 cm	M3	>4 kg	Hook, span, pulp pinch	240°
2 cm	M4	>3 kg	Hook, span, key, chuck, pulp pinch	240°
3 cm	M3	>2 kg	Hook	210°
4 cm	M3	>3 kg	Hook	180°
3 cm	M4	>3 kg	Hook, key	210°

ROM: Range of motion

patients also underwent simultaneous or secondary ancillary procedures. None of them got a power grasp. One patient underwent a secondary procedure for thumb abduction using a tendon graft from brachialis to APB, but did not achieve enough handgrip and needed further procedures for the improvement of the same. Three patients did not undergo any secondary procedures, still are under follow up and will need additional procedures to further improve functionality of the hand despite having a flexion range [Figures 10-12].

## DISCUSSION

Restoration of hand function after C7–T1 brachial plexus injuries has long been challenging for surgeons. Tendon transfers are a routine procedure used to improve hand function in brachial plexus injuries. The choice of donor motor for the restoration of digital flexion has been extensor carpi radialis longus (ECRL); this assumes a functioning ECRB and takes advantage of the synergism in

finger flexion and wrist extension.<sup>[9]</sup> Biceps (reinnervated or normal) or the brachialis has also been used for transfer to the FDP tendons but with the addition of a tendon graft usually harvested as a fascia lata graft.<sup>[10,11]</sup>

BR due to its high innervation (C5, C6) is a valuable option as a donor to restore finger flexion in the lower plexus type of palsies. Not many studies are available describing the use of BR to restore finger flexion. Although excursion of BR is (3 cm) less compared to FDP (7 cm), after complete fascial release, there is 2–3 cm increase in excursion, which is comparable to ECRL.<sup>[12]</sup>

In our study, presentation since time of injury was 10–30 months, leaving no option of nerve repair or transfer. Movement was achieved by 3 months



Figure 9: Measuring hook grip strength



Figure 11: Chuck grip



Figure 10: Pin grip



Figure 12: Functionality of reconstructed hand

post-operatively with no prolonged lag period. Power of finger flexion was M4 in four patients and M3 in four patients. Xu *et al.* study of finger flexion strength after brachialis motor branch transfer<sup>[13]</sup> has only corresponded to the MRC Grades M2–M3, lowering the grip strength and practical value of the reconstructed hand. To obtain satisfactory hand function, combined nerve and tendon transfers were done in staged procedures. Nerve transfer was done within 5 months since the time of injury. Second surgery was performed 9 months after the first with power of finger flexion M3 and 30 months follow-up showed M4 power in three fingers. Brachioradialis tendon was transferred to APB to restore thumb opposition.

Total active range of movement achieved in our present series in eight cases who came for follow-up was between 180° and 270°. Doi *et al.*<sup>[14]</sup> in their case series achieved total active range of movement of the fingers between 70° and 110° following free functional muscle transfer with gracilis muscle.

Mohindra *et al.*<sup>[15]</sup> showed that, for key pinch reconstruction, both BR and PT turned to be equally efficacious donors, while for hook reconstruction, PT and BR transfer to FDP turned out to be superior to FDP tenodesis in tetraplegic hands for the restoration of finger flexion and key pinch. In lower plexus type of injury, if PT is used as a donor, pronation may be affected due to lower trunk innervation of pronator quadratus by the anterior interosseous nerve (C8, T1).

## CONCLUSION

The BR is effective in providing adequate range and power of finger flexion; this muscle is always preserved in lower plexus injuries due to high innervation (C5, C6). It is expendable as an elbow flexor. A comparable excursion to that of the ECRL can be achieved after complete fascial release; this makes it valuable in allowing wrist extension to be conserved. This is important as only two of the 11 patients with lower plexus injuries in this series had a normal wrist extension. Although the pronator teres could also be used,<sup>[16]</sup> the absence of a pronator quadratus, which is innervated by the anterior interosseous nerve (C8, T1) could deprive forearm pronation. It is true that further functional improvement necessitates other tendon transfers and strategic arthrodesis.

## Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

## Conflicts of interest

There are no conflicts of interest.

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