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ORIGINAL ARTICLE

Distal Nerve Transfers in Restoration of Elbow Flexion and Hand Functions in Brachial Plexus and Peripheral Nerve Injuries

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Abstract

Background: Surgical management of brachial plexus and peripheral nerve injuries remain a challenging problem. The focus of peripheral nerve surgery is gradually shifting form nerve graft recon-struction to distal nerve transfers. Distal nerve transfers have become the standard of care in brachial plexus and high peripheral nerve injuries in many centres. The authors describe their experience in distal nerve transfers for restoration of elbow flexion and hand functions in brachial plexus and high peripheral nerve injuries.

Material & Methods: 14 patients with brachial plexus injuries and high peripheral nerve injuries underwent reconstruction to restore elbow flexion and hand functions. The mean age was 31 years (range 22-43) and mean time to surgery after injury was 7.7 months. Follow up averaged 18 months.

Results: Good to excellent recovery (more than M4 power) was seen in 5 of 7 patients in bifasicular nerve transfers for elbow flexion and in 2 patients with high radial nerve injury. Of 3 cases with ulnar nerve injury nerve transfers resulted in good key pinch function in two patients and satisfactory pinch function in one. Both patients with high median nerve injury and lower brachial plexus injury had post operative poor finger flexion.

Conclusion: Distal nerve transfers must be considered for useful restoration of elbow flexion in upper brachial injuries as also in patients with high peripheral nerve and lower brachial plexus injuries for improving hand function.

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Introduction

Brachial plexus and peripheral nerve injuries are challenging problems requiring comprehensive care. Nerve graft reconstruction was considered the procedure of choice until late 1990's in cases where primary repair of injured nerve was not feasible. Reconstruction with nerve grafts is time consuming and associated with poor to fair recovery after long term follow up.[1] Currently, distal nerve transfers form a viable option in reconstruction of brachial plexus and upper limb peripheral nerve injuries. The aim of this article is to share the experiences gained in nerve transfers for restoration of elbow flexion and hand function in high peripheral nerve injuries of upper limb.

Materials & Methods

14 patients with brachial plexus and upper extremity nerve injuries were included to restore elbow flexion and hand function. Loss of elbow flexion was due to upper brachial plexus injury while loss of wrist and hand functions were due to lower brachial plexus, proximal radial, median and ulnar nerve injuries. Loss of elbow extension was not targeted as we believe that elbow extension is achieved with the aid of gravity. Therefore all patients were sub grouped as (i) loss of elbow flexion due to upper brachial plexus injury, (ii) high median nerve injury, (iii) high ulnar nerve injury, (iv) high radial nerve injury and (v) lower brachial plexus injury (C8-T1 lesions). Combined lesions with multiple nerve involvement were excluded from the study. Distal nerve transfers to restore elbow flexion were done using double fascicular nerve transfer described by Oberlin, Tung and Ray in which a fascicle of ulnar nerve was transferred to biceps branch of musculocutaneous nerve and fascicle of median nerve was transferred to brachialis branch (Fig 1-3).[2,3,4] In high median nerve injury, and lower brachial plexus injury, the brachialis branch of musculocutaneous nerve was used to target the anterior interroseous nerve (AIN). The technique described by Ray et al. was used for this transfer.[5] In high radial nerve injury which was irreparable primarily, the flexor carpi radialis

branch (FCR) of median nerve was transferred to Posterior Interroseous nerve (PIN) and one fascicle to flexor digitorum superficialis (FDS) was transferred to Extensor carpi radialis brevis (ECRB) branch of radial nerve (Fig 4-7).[6] In high ulnar nerve injury Pronatus quadratus branch of AIN was transferred to motor branch of ulnar nerve in distal forearm[7] (Fig 8-11). A nerve stimulator was used to locate the donor nerves in all cases. In the post operative period the upper limb and hand were immobilised for 3 weeks. Joint mobilization and muscle strengthening exercises were begun after 3 weeks and all patients were followed up for 18 months and the recovery of muscle power recorded as per Medical Research Council (MRC) Scale of muscle strength. At the end of 18 months the outcome was graded as poor (M < 2or 2); satisfactory (M3), good (M3+ and M4) and excellent (M4+ and 5).

Fig. 1 Patient with poor elbow flexion

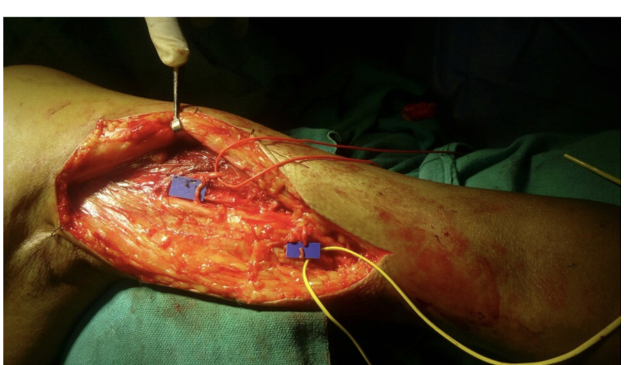

Fig. 2 Bifasicular nerve transfer

Fig. 3 Good elbow flexion

Fig. 4 Gunshot wound arm

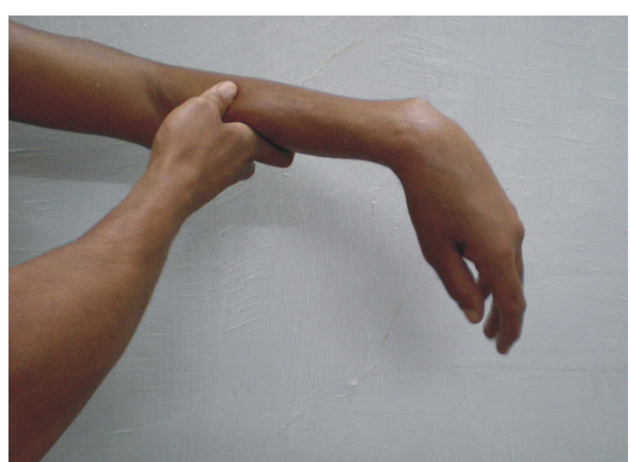

Fig 5 High radial nerve injury

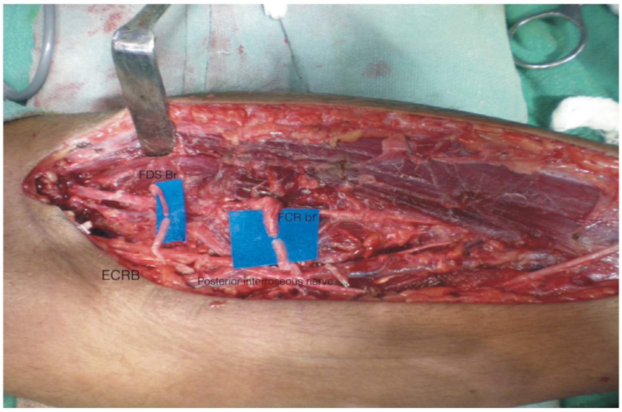

Fig. 6 FCR to PIN transfer, FDS branch to ECRB transfer

Fig. 7 Post op good wrist and finger extension

Fig. 8 Missile injury of elbow with soft tissue defect and ulnar nerve injury

Fig. 9 Soft tissue reconstruction with thoracoumbilical flap.

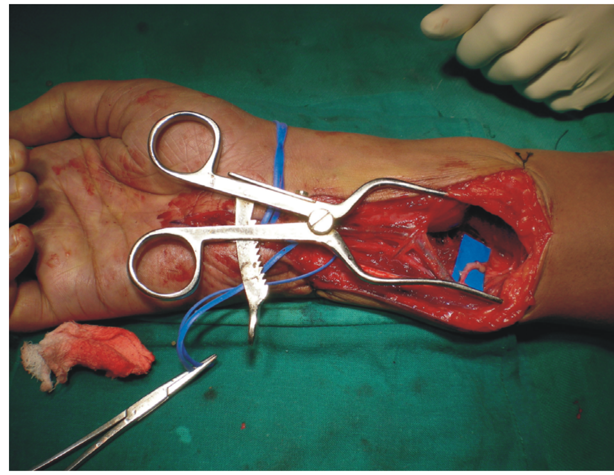

Fig. 10 Pronator quadratus branch transfer to motor branch of ulnar nerve

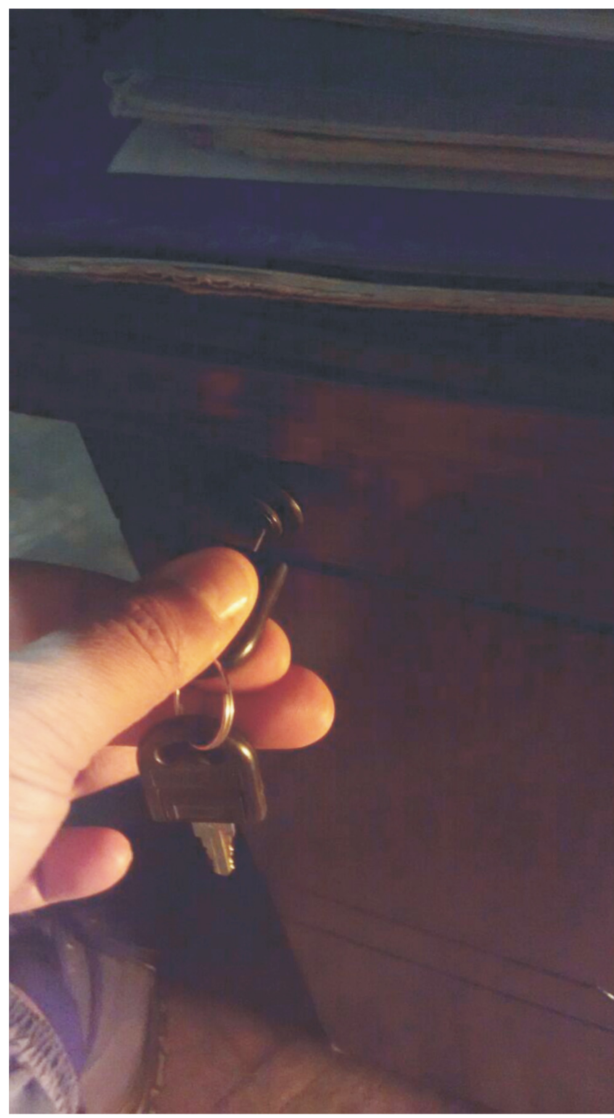

Fig. 11 Good lateral key pinch grip.

Results

A total of 14 patients were included in the study and all were males. The results are summarized in Table 1. The most common mode of injury was two wheeler road traffic accidents. (Table 2) Mean age of patients with injuries was 31 years (Range 22-43 years). Mean time for surgery was 7.7 months after the injury. Five of seven patients with upper brachial plexus injuries who underwent bifasicular nerve transfers had good to excellent recovery and both the patients with high radial nerve injury had similar outcomes. Both patients with high median nerve injury and lower Brachial Plexus Injuries had poor finger flexion. With ulnar nerve injury nerve transfer resulted on good key pinch function in two patients and satisfactory pinch function in one patients.

Table 1 (Summary)

S.No	Age	Mode of Injury	Motor deficit	Neurological involvement	Operative procedure	Timing of surgery (months)	Functional outcomes	Other ancillary procedure
1	24	Road Traffic Accident(RTA)	Shoulder abduction M0 Elbow flexion M0	C5-C6 injury	Bifasicular nerve transfer	06	Elbow flexion M4+	Spinal Asscessory (SA) to Suprascapular nerve (SSN) transfer and Long head triceps (LHT) branch to Axillary (Ax) nerve
2	28	RTA	Shoulder abduction M0 Elbow flexion M0	C5-C6 injury	Bifasicular nerve transfer	10	Elbow flexion M4	SA to SSN LHT to Ax
3	32	Fall from height	Shoulder abduction M0 Elbow flexion M0	C5-C6 injury	Bifasicular nerve transfer	08	Elbow flexion M3+	SA to SSN LHT to Ax
4	34	Penetrating injury arm	Index finger flexion M0 Thumb pinch M0 Opposition Kapandji Scale 5	HMNI	Brachialis nerve to AIN transfer	11	Finger flexion M2 Thumb pinch M3	Nerve grafts 4.0 cms to repair median N
5	23	RTA	Shoulder abduction M0 Elbow flexion M0	C5-C6 injury	Bifasicular nerve transfer	10	Elbow flexion M4	SA to SSN LHT to Ax
6	31	Missile injury elbow	Weak hand intrinsic muscle ulnar nerve Key pinch M0	High ulnar nerve injury	AIN pronator branch to motor branch of ulnar nerve	05	Key pinch M4	Soft tissue reconstruction of elbow defect
7	30	RTA	Shoulder abduction M0 Elbow flexion M0	C5-C6 injury	Bifasicular nerve transfer	06	Elbow flexion M4	SA to SSN LHT to Ax
8	43	Penetrating injury arm	Weak hand intrinsic muscle ulnar nerve Key pinch M0	High ulnar nerve injury	AIN pronator branch to motor branch of ulnar nerve	7	Key pinch M3	Nil
9	30	Gunshot wound arm	Wrist extension M0, Finger extension M0, Thumb extension M0	High radial nerve injury	FCR br to PIN, FDS br to ECRB	6	Wrist extension M4+, Finger extension M4 Thumb extension M4	Skeletal stabilisation and soft tissue reocnstruction of arm defect
10	24	RTA	Shoulder abduction M0 Elbow flexion M0	C5-C6 injury	Bifasicular nerve transfer	7	Elbow flexion M4	SA to SSN LHT to Ax
11	34	Fall from height	Long flexors of finger M0	C8-T1	Brachialis nerve to AIN transfer	9	Finger flexion M2 Thumb pinch M2	Nil
12	36	RTA	Shoulder abduction M0 Elbow flexion M0	C5-C6 injury	Bifasicular nerve transfer	10	Elbow flexion M3+	SA to SSN LHT to Ax
13	43	RTA	Wrist extension M0, Finger extension M0, Thumb extension M0	High radial nerve injury	FCR br to PIN, FDS br to ECRB	8	Wrist extension M4, Finger extension M4 Thumb extension M4	Skeletal stabilisation of humeral fracture, Exploration of radial nerve with long segment involvement
14	22	Penetrating injury arm	Weak hand intrinsic muscle ulnar nerve Key pinch M0	High ulnar nerve injury	AIN pronator branch to motor branch of ulnar nerve	6	Key pinch M3	Nil

Table 2: Mode of injury

Mode of injury	Number
Road traffic accidents	7
Gunshot or missile injury	2
Penetrating sharp injury	3
Fall from height	2

Discussion

The concept of nerve transfers has evolved from the experience gained by nerve repairs and grafting procedures in brachial plexus and peripheral nerve injuries. Unpredictable results of long nerve grafts and proximal nerve repair lead to the abstraction of nerve transfers which is gradually being accepted as a new emerging modality in brachial plexus and peripheral nerve surgery of upper extremity. Poor outcomes of nerve repair have been attributed to proximal lesions, tension at the repair site, delayed repair, long nerve grafts and inappropriate internal nerve topography.[1] Nerve transfers address these drawbacks and are now being increasingly used for restoring upper limb function. Nerve transfers involve coapting a healthy functional dispensable donor nerve or fascicle to a denervated nerve to restore the desired function. The advantages of nerve transfers are that the coaptation of donor to the recipient nerve is close to the target muscles or sensory territory. The donor can be selected as pure motor or sensory and nerve grafts avoided.[8,9]

In restoring function of the paralysed upper extremity, elbow flexion is the most important of all the functions to be restored as it allows the hand to be in position for daily activities. Transfer of an ulnar nerve radicle to the biceps branch of musculocutaneous nerve and median nerve fascicle to brachialis branch have resulted in achieving good elbow flexion.[2,3] Double fascicular nerve transfers are suitable for upper brachial plexus lesions involving C5-6 roots with preserved hand function. This combined procedure is helpful in achieving good to excellent elbow flexion power in patients with upper Brachial PIexus Injuries. (BPI)[10,11,12] Of the 7 patients with upper Brachial plexus injury who underwent bifasicular nerve transfers 4 had excellent results with more than M4 muscle power. We therefore consider this to the procedure of choice in achieving elbow flexion in C5-C6 injuries.

In lower Brachial plexus injuries involving C8-T1 roots and high median nerve injuries (HMNI), restoring hand function remains a challenge to peripheral nerve surgeons. C8-T1 injuries produce variable ulnar and median nerve deficit. Therefore achieving grasp and pinch functions of the hand becomes important in restoring upper extremity function. In preserved elbow flexion, brachialis branch to AIN has been used to restore these functions.[5] HMNI has similar functional deficit but with intact ulnar nerve functions. However, HMNI are uncommon injuries accounting for less than 0.1% of upper extremity nerve injuries. They involve the median nerve proximal to the origin of AIN.[13,14] HMNI produces significant sensory and motor deficits. The most common motor deficits involve loss of opposition in about 30% of patients, no index finger flexion, a weak grasp with absent thumb interphalangeal joint flexion. Forearm pronation is weak but with preserved middle finger flexion. Sensory deficits include loss of protective sensation form the pulp of thumb, index and middle fingers.[15] In restoring the thumb and index finger flexion along with grasp and pinch strength, the brachialis to AIN transfer has shown satisfactory results.[5,16] Of the 3 patients with C8-T1 injury and HMNI, only one patient had satisfactory outcomes in terms of hand grasp function and thumb pinch function. This can be attributed to delayed presentation and late surgery. In one patient with HMNI the median nerve was also reconstructed with 4 cms cable graft in order to give a fair chance of sensory recovery. Nevertheless this transfer does provide a viable option in otherwise a less favourable situation. Another transfer that has recently been reported and considered superior to these transfers are nerve to ECRB to AIN, in which the authors reported a grasp strength and pinch strength of 5kg and 2 kg respectively.[17]

High radial nerve injury occurs at the level of humeral shaft and is characterised by wrist, finger and thumb drop resulting in inability to open the palm fully and compromised hand function.[18] When primary repair of radial nerve is not feasible, reconstruction of radial nerve using cable grafts remains the mainstay of management. However the results of long gap nerve reconstruction are unpredictable with high failure rates to an extent of 42%, more so in untidy wounds and late repair.[19] Tendon transfers for radial nerve injuries have been the mainstay for improving the hand functions in unrecovered injuries and with delayed presentation. However the disadvantages associated with tendon transfers prompted the peripheral nerve surgeons to explore the alternatives in form of nerve transfers. Susan Mackinnon described the transfers of median nerve branches to radial nerve to achieve the desired functions.[20] The motor donor which can be used for transfers are FDS branch to ECRB, flexor carpi radialis branch to posterior interroseous nerve and pronator teres to extensor carpi radialis longus (ECRL).[21,22] Our experience in high radial nerve injury was limited to two cases who had undergone FDS to ECRB and FCR to PIN transfer with resultant M4 wrist, fingers and thumb extension. One patient was of gunshot wound arm with an open fracture humerus and soft tissue loss . The second patient had a closed humerus fracture but a large segment of fibrosed radial nerve precluded nerve repair. The results are encouraging and we hope to study more such cases before drawing conclusions.

Repair of proximal ulnar nerve injuries are associated with poor recovery of hand intrinsic functions.[23] Selective distal nerve transfer to restore intrinsic function and sensory deficit have been reported from 1997 onwards.[24,25] The simplest technique to restore motor functions of hand in high ulnar nerve injury is achieved by transfer of AIN branch supplying pronator quadratus to motor branch of ulnar nerve at the level of wrist along with decompression of Guyon's canal.[26] We used this transfer in 3 patients and we were able to achieve M3 key pinch power in 2 patients and M4 key pinch power in one patient. Though this number is far too small to arrive at definite conclusions, it is in keeping with the current literature which favours this transfer for high ulnar nerve injury. Various authors have reported good recovery of hand intrinsics and 6 fold increase in lateral key pinch strength and grip strength.[27,28] Flores compared the outcomes of nerve grafting vs distal motor and sensory nerve transfers in high ulnar nerve injuries. The nerve transfer group had higher recovery (M3/M4 grip strength). Both groups however had similar sensory recovery.[29] Sensory nerve transfers at our centre are still under evaluation and we hope to publish combined results of these transfers.

Conclusion

Distal nerve transfers are being increasingly used in proximal nerve injuries of upper extremity and Brachial Plexus Injuries. The results have been encouraging and therefore their role has been expanding to address the deficits in spinal injuries as well. With the available set of nerve transfers in upper extremity, a reasonable functional outcome can be expected in proximal nerve injuries and Brachial plexus injuries.

References

1. Mackinnon SE. Donor distal, recipient proximal and other personal perspectives on nerve transfers. Hand Clin 2016; 32:141-151.
2. Oberlin C, Beal D, Leechavengvongs S et al. Nerve transfers to biceps muscle using part of ulnar nerve for C5-C6 avulsion of brachial plexus : anatomical study and report of four cases. J Hand Surg Am 1994;94(2):232-237.
3. Tung TH, Novak CB, Mackinnon SE. Nerve transfers to biceps and brachialis branches to improve elbow flexion strength after brachial plexus injuries. J Neurosurg 2003;98(2):313-318
4. Ray WZ, Pet MA, Yee A et al. Double fascicular nerve transfer to the biceps and brachialis muscles after brachial plexus injury: clinical outcomes in a series of 29 cases. J Neurosurg 2011;114(6):1520-1528.
5. Ray WZ, Yarbrough CK Yee et al. Clinical outcomes following brachialis to anterior interroseous nerve transfers. J Neurosurg 2012;117(3):604-609.
6. Mackinnon SE, Colbert S. Nerve transfers in Hand and Upper Extremity. In Techniques in Hand and Upper Extremity Surgery . Doyle JR, Jupiter JB:,Ed. Lippincott Williams 2008; 12(1): 20-33.
7. Novak CB, Interroseous SE. Distal anterior interroseous nerve transfer to deep motor branch of ulnar nerve for reconstruction of high ulnar nerve injuries. J Reconstr Microsurg 2002;18:459-464.
8. Lee SK, Wolfe SW. Nerve transfers for the upper extremity: new horizons in nerve reconstruction. J Am Acad Orthop Surg 2012;20(8):506-517
9. Moore AM. Nerve transfers to restore upper extremity functions: a paradigm shift. Frontiers in Neurology 2014;5:40.
10. Bhandari PS, Sadhotra LP, Bhargava P et al. Surgical outcomes following nerve transfers in upper brachial plexus injuries. Indian J Plast Surg 2009;42(2):150-160.
11. Venkatramani H, Bharadwaj P, Faraquee SR, Sabapathy SR. Functional outcome of nerve transfer for restoration of shoulder and elbow function in upper brachial plexus injury. J Brachial Plexus and Peripheral Nerve Surgery 2008;3:15.
12. Estrella EP. Functional outcomes of nerve transfers for upper type brachial plexus injuries. J Plast Reconst Aesth Surg 2011;64(8): 1007-1013.
13. Lad SP, Nathan JK, Schubert RD et al. Trends in Median, ulnar, radial and brachioplexus nerve injuries in United States. Neurosurgery 2010;66(5): 953-960.
14. Soldado F, Bertelli JA, Ghizoni MF. High median nerve injury: Motor and sensory nerve transfers to restore functions. Hand Clin 2016;32: 209-217
15. Bertelli JA, Doldado F, Lehn VL et al. Reappraisal of clinical deficits following high median nerve injuries. J Hand Surg Am 2016;41(1):13-19

16. Palazzi S, Palazzi JL, Caceres JP. Neurotization with the brachialis muscle motor nerve. Microsurgery 2006;26:330 333.
17. Bertelli JA. Transfers of the radial nerve to extensor carpi radialis brevis to anterior interroseous nerve to reconstruct thumb and finger flexion. J Hand Surg Am 2015;40(2):323-328.
18. Ljuquist KL, Martineau P, Allan C. Radial nerve injuries. J Hand Surg Am 2015; 40(1): 166-172.
19. Shergill G, Bonney G, Munshi P et al. The radial and posterior interroseous nerves: Results of 260 repairs. J Bone J Surg Br 2001; 83(5): 646-649.
20. Mackinnon SE, Rogue B, Tung TH. Median to radial nerve transfer for treatment of radial nerve palsy. J Neurosurg 2007;103(3): 666-671.
21. Ray WZ, Mackinnon SE. Clinical outcomes following median to radial nerve transfers. J Hand Sure Am 2011;36(2):201-208.
22. Garcia- Lopez, Navarro R, Martinez F et al. Nerve transfers from branches of flexor carpi radialis and pronator teres to reconstruct the radial nerve. J Hand Surg Am 2014;39(1): 50-56.
23. Gaul JS. Intrinsic motor recovery- a long tern study of ulnar nerve repair. J Hand Surg Am 1982;7(5): 502-508.
24. Wang Y, Shengxiu Z. Transfer of a branch of the anterior interroseous nerve to motor branch of median and ulnar nerve. Chin Med j 1997;110(3):216-219.
25. Brown JM, Yes A, Macinnon SE. Distal median to ulnar nerve transfers to restore ulnar motor and sensory functions of hand: technical nuances. Neurosurgery 2009; 65(5): 966-978.
26. Patterson JMM. High ulnar nerve injuries: Nerve transfers to restore functions. Hand Clin 2016;32:219-226.
27. Novak CB, Mackinnon SE. Distal anterior interroseous nerve transfer to the deep motor branch of the ulnar nerve for reconstruction of high ulnar nerve injuries. J Reconstr Microsurg 2002;18:459-464.
28. Haase SC, Chung KC. Anterior interroseous nerve transfer to motor branch of ulnar nerve for high ulnar nerve injuries. Ann Plastic Surg 2002;49(3): 285-290.
29. Flores LP. Comparative study of nerve grafting vs distal transfer for the treatment of proximal injuries of the ulnar nerve. J Recons Microsurg 2015;31(9): 647-653.