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ORIGINAL PAPER

Extensor indicis opponensplasty: a modified evaluation system

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Abstract

Background Extensor indicis opponensplasty is the gold standard treatment for the restoration of opposition in individuals with median nerve injuries, and it has excellent outcomes. Most authors have used the Sundraraj and Mani scoring system, which considered a thumb reaching any fingertip as a good or excellent outcome. To refine the technique for extensor indicis opponensplasty, we propose an informative yet simple system to describe outcomes.

Methods This study included 13 patients who underwent extensor indicis opponensplasty for median nerve injuries, with four isolated and nine combined. Six patients had triple insertions, and seven had single/double insertions. The patients were evaluated using the Sundraraj and Mani system and our proposed system for the primary outcome. Secondary outcomes included return to productivity and complications.

Results We demonstrated that 92% of the patients achieved excellent results according to the Sundraraj and Mani system. We achieved pulp to little pulp (5A) in seven patients, tip to little pulp (5B) in two patients, pulp to ring pulp (4A) in one patient, tip to ring pulp (4B) in one patient, pulp to middle finger pulp (3A) in one patient, and fair opposition (1) in one patient. A 5A score was achieved in five patients with triple insertion.

Conclusions The new system proposed in this study better facilitates the comparison of technical variations of opponensplasty.

Level of evidence:Level IV, therapeutic study.

Keywords Extensor Indicis · Tendon transfer · Opponensplasty · Median nerve injury · Evaluation

Introduction

Having a hand with an opposable thumb has allowed the human race to make great advances. Its functional and aesthetic considerations cannot be overestimated [1]. Aristotle asserted that the hand (along with reason and speech) separated humans from other animals. Hippocrates (460–370 BC) referred to the thumb as the anti-hand, which resisted the power of all the other digits [2, 3].

Opposition is a composite motion involving at all three thumb joints, with abduction, pronation, and flexion occurring at the carpometacarpal joint; abduction and flexion occurring at the metacarpophalangeal joint; and either flexion or extension occurring at the interphalangeal joint. This allows the thumb to move into position in front of the other fingers to hold objects against them [4].

Median nerve palsy with loss of opposition is devastating and results in the loss of 50% of all hand functions. Hence, every attempt should be made to restore opposition. Extensor indicis proprius (EIP) opponensplasty is considered by many to be the gold standard for restoring opposition in the post-traumatic setting [5–8].

Transferring the EIP to restore opposition has several advantages. It should be considered especially in the traumatic setting with lacerated flexor tendons. Furthermore, there is minimal donor site morbidity. Additionally, it preserves the extrinsic digital flexors as donors for the intrinsic reconstruction of combined median/ulnar nerve injuries. In addition, it is very useful in the setting of proximal median nerve palsy, in

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which the flexor digitorum superficialis (FDS) tendons are unusable. Finally, this technique does not require the surgical creation of a pulley, as the transfer around the ulna results in an ideal vector to achieve opposition [9].

A variety of attachments have been described for inserting the EIP to restore opposition. In general, compared with insertions located on the dorso-ulnar aspect of the MP joint, insertions at the radio-palmar aspect of the metacarpophalangeal joint (MP) result in better pulp-to-pulp pinch [10].

Littler wove the transferred tendon into the abductor pollicis brevis tendon (ABP). Riordan described a sequential insertion of the transferred tendon into the ABP tendon with continuation of the tendon distally into the extensor hood of the thumb MP joint and the extensor pollicis longus (EPL). Brand wove one half of the transferred tendon into the ABP and EPL and the other half of the tendon into the adductor pollicis (AdP). Dual insertions into the APB and either the dorsal MP joint capsule or the thumb extensor expansion have been described for the intrinsic minus thumb [11–14].

Many authors used the Sundraraj and Mani or the Jacob and Thompson scoring systems to describe their outcomes (Table 1). The Mehta and Malivaya evaluation system was devised in 1996 and was more comprehensive and complex than the previous systems (Table 2). Kapandaji used a numerical scale in a study with children according to the position the thumb pad can reach when attempting opposition (Fig. 1) [15–18].

When addressing EIP opponensplasty, we found that two technical aspects remained unresolved. First, a universal scoring system is still lacking. Second, it is unclear which insertion technique should be used for each type of deformity.

The aim of the study was to propose a modified classification system that combines the advantages of the previously described evaluation systems together in a simple, functionally oriented, informative system and to demonstrate the effectiveness of the system through the authors' experience in EIP opponensplasty by comparing it to the other available evaluation systems.

Table 2 Mehta and Malivaya evaluation system

Criteria (parameter)	score
1. Position of thumb at rest	
Normal	5
In front of palm	3
Behind the palm	0
2. Range of active abduction of thumb	
> 45°	5
41 to 45°	4
36 to 40°	3
35 or < 35°	0
3. Position of terminal phalanx of thumb	
(a) At rest	
Up to 20° flexion	4
21 to 45° flexion	3
> 45°	2
(b) On pinching	
Up to 25° flexion	5
26 to 45° flexion	3
> 45 °	0
4. Pattern of pinch	
Pulp to pulp	3
Pulp to side	2
5. Strength of pinch (pulp to pulp—tripod)	
Good (> 50% of normal)	3
Fair (21 to 50% of normal)	2
Poor (< 20% of normal)	1

Materials and Methods

The study was conducted from May 2014 to May 2017. Patients meeting the following criteria were included in the study design.

Inclusion criteria

- Patients between 10 and 60 years of age
- No gender restriction

Table 1 Two methods for assessing opponensplasty

	Sundararaj and Mani, 1984	Jacob and Thompson, 1960
Excellent	Opposition to ring or little fingertip with IP joints extended	75% of function of opposite thumb when normal OR < 20°of difference between the planes of the opposed thumbnail and the palm with good power
Good	Opposition to index or middle fingertip with IP joint extended	
Fair	Thumb IP joint flexes during opposition	Full, though weak, opposition or restricted, but strong, opposition OR no opposition restored
Poor	No opposition restored	

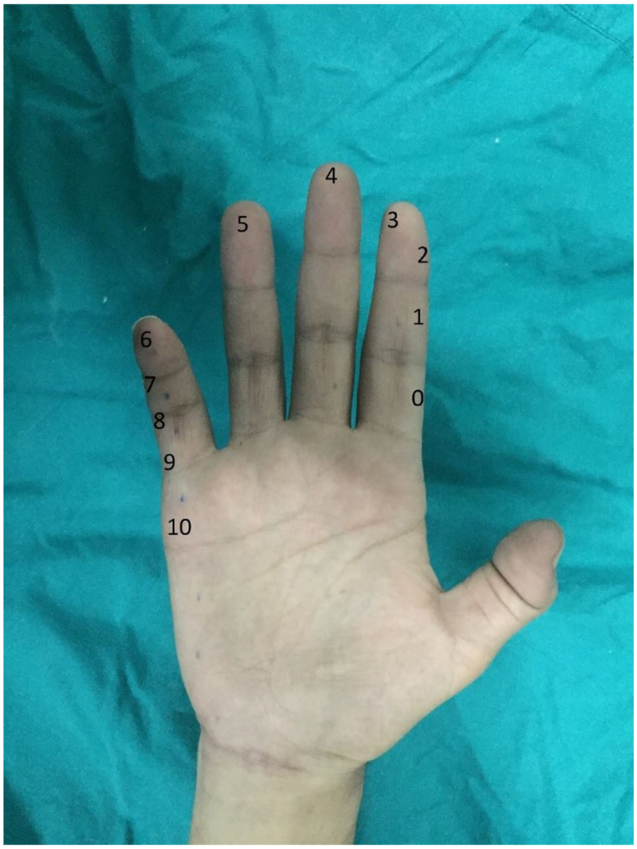

Fig. 1 Kapandaji scoring system

- Patients who suffered a traumatic nerve injury
- Patients in whom nerve regeneration, whether spontaneous or after nerve repair, is no longer expected.
- Patients who presented early yet requested an early return to work

Exclusion criteria

- Patients who dropped out of the physiotherapy programme
- Patients who suffered traumatic injuries proximal to the brachial plexus
- Patients with significant soft tissue contractures beyond repair
- Patients with joint stiffness that is not responsive to physiotherapy
- Patients with immature scarring from a previous surgery
- Patients with ischaemia in the hand
- Patients with a non-recovering insensate hand

This study was designed as a case series in which 13 late posttraumatic median nerve palsies were treated with EIP opponensplasty. The mean age of the patients was 32.8 years. There was a marked male predominance in the study group ($n = 12$). Of these 13 patients, 4 had isolated median nerve injuries, and 9 had combined nerve injuries. Four patients had proximal injuries, while the rest had distal injuries. Glass was the most frequently encountered causative tool in five cases.

The average interval between injury and intervention was 18 months. The patient history collected included a detailed trauma history, hand dominance, occupational history, and previous surgeries. The preoperative examination included an investigation of the movements at the carpometacarpal (CMJ) and MP joints of the thumb. Additionally, the ability to independently extend the index finger was routinely assessed. Preoperative nerve conduction studies and electromyography including of the EIP were performed in all patients.

Immediately prior to surgery, we marked our incision sites and the proposed EIP track around the ulna (video presentation 1). When harvesting the EIP tendon, we included part of the extensor expansion with the tendon to obtain a sufficiently long tendon segment. In the intrinsic minus thumb, we inserted the tendon sequentially through the ABP tendon, then to the volar radial aspect of the MP joint and finally into the thumb extensors. We used polypropylene 3–0 sutures to secure our insertions, starting with the MP joint capsule with the thumb in maximal abduction and internal rotation and the tendon under maximum tension and followed by the extensor apparatus with the MP joint at 40° of flexion. The last stitch was then made to secure the interweaving through the ABP (Fig. 2).

The thumb was immobilized at maximal abduction in a dorsal slab for 4 weeks. Then, patients were referred to the hand therapist to gradually start range of motion exercises for the thumb. After the completion of follow-up (mean 10 months), the final outcome was recorded using the Sundraraj and Mani scoring system, the kapandaji numerical scale and our proposed scoring system (Table 3). Complications and return to productivity were recorded as secondary outcomes.

Results

According to the Sundraraj and Mani system, when the EIP was used as the donor, the results were excellent to good in 12 out of 13 patients, and patient had a fair result (Fig. 3). According to the Kapandaji scoring system, we had one patient with a score of 10, one patient with a score of 9, two patients with scores of 8, one patient with a score of 7, five patients with scores of 6, two patients with scores of 5, and one patient with a score of 2. Using our scoring system, we had seven patients who achieved 5A scores (video 2), two patients with 5B scores, one with a 4A score, one with a 4B score, one with a 3A score, and one patient with a score of 1.

Only one patient in our series suffered an extensor lag in the index finger following harvesting of the EIP (the only female in the study population). The patient with a fair result previously

Fig. 2 Steps for performing opponensplasty. **a**, **b** Harvesting the extensor indicis. **c**, **d** Rerouting the tendon around the ulna. **d**, **e** Inserting the tendon and setting the tension in maximum opposition

suffered a proximal combined nerve injury following a supracondylar fracture that affected the median and ulnar nerves and a mild lesion involving the radial nerve. A preliminary neurolysis was performed 6 months prior to the intervention.

Among the 13 patients in our study, 1 patient was an unemployed housewife, and 2 patients failed to return to work. Among the remaining 10 patients, the average time that passed prior to their return to work after the operation was 4.1 months.

Table 3 Our proposed evaluation system for opponensplasty

5	Thumb to little finger	A	Pulp to pulp
		B	Tip to pulp
4	Thumb to ring finger	A	Pulp to pulp
		B	Tip to pulp
3	Thumb to middle finger	A	Pulp to pulp
		B	Tip to pulp
2	Thumb to index finger	A	Pulp to pulp
		B	Tip to pulp
1	Thumb lies in front of the index finger yet does not reach its tip		
0	No opposition restored		

Case 1 (Fig. 4)

A 19-year-old housewife presented with an old median nerve injury that had occurred 2 years earlier. On presentation, she suffered from loss of opposition and a painful neuroma on the wrist with intact hand sensation. She underwent EIP opponensplasty with triple insertion and dermo-fat grafting around the neuroma. The outcome was 5A opposition

Fig. 3 Score of 5A with pulp to pulp opposition (left) and a score of 1 with fair opposition (right)

Fig. 4 Case 1 preoperation (left) and 6 months postoperation in the 5A position, with a Kapandaji score of 9

according to our scoring system and 9 according to the Kapandaji scoring system. She developed an extensor lag of her index finger, and no return to work was measured.

Case 2 (Fig. 5)

A 37-year-old clerk presented with an isolated ulnar nerve injury that had occurred 2 years earlier. However, the examination revealed that the patient had suffered loss of opposition and complete simple clawing, signifying a possible Martin Gruber anastomosis. The patient underwent EIP opponensplasty with triple insertion and FDS lasso to correct the clawing. The patient experienced fully restored thumb opposition with a 5A score according to our scoring system and a Kapandaji score of 10. The postoperative course was eventless. However, the patient failed to return to work after 10 months of follow-up.

Case 3 (Fig. 6)

A 32-year-old male vendor who had suffered proximal ulnar and median nerve injuries 7 months earlier had loss of opposition with intact flexor pollicis brevis (FPB) action and Wartenberg deformity of the little finger. Cable grafting of the median nerve was performed together with neurolysis of the ulnar nerve. Then, EIP opponensplasty was performed with a double insertion, in addition to a split extensor digiti minimi (EDM) transfer to correct the little finger abduction. He regained full opposition, with a score of 5A. However, he had a Kapandaji score of 6 due to deficient flexor pollicis longus (FPL) action. The postoperative course was eventless, and he was able to resume his job after 6 months.

Case 4 (Fig. 7)

A 57-year-old clerk presented with left proximal ulnar, median, and mild radial nerve injuries after sustaining a supracondylar fracture. All his long flexors were paralyzed except that of his middle finger, and he had no oppositional ability. He underwent preliminary neurolysis for the median and ulnar nerves and anterior transposition of the ulnar nerve. Six months later, he underwent transfer of brachioradialis (Br)-FPL, extensor carpi radialis brevis (ECRB)-little and -ring flexor digitorum profundus muscle (FDP), middle FDP-index FDP, and EIP opponensplasty. Despite significant improvement of the long flexors, the patient had poor oppositional ability, with a score of 1 according to our system and a Kapandaji score of 2. The patient returned to work 1 month later.

Fig. 5 Case 2 preoperation (left) and 6 months postoperation in the 5A position (right), with a Kapandaji score of 10

Fig. 6 Case 3 preoperation (left) and 9 months postoperation in the 5A position, with a Kapandaji score of 6 (right)

Discussion

Enthusiasm for developing different tendon transfer procedures has waned in the past two decades, with few innovations and additions to these valuable tools used to address nerve injuries. Hence, this field has been stagnant for some time. Most of the papers that have been published over the last two decades were criticisms of the techniques developed by the pioneers of tendon transfer surgery, such as Brand, Bunell, Burkhalter, Zancolli, and Omer in the twentieth century.

As distal nerve transfer procedures with promising outcomes evolve, enough data should become available to allow a comparison of their outcomes to those of the previously established tendon transfer techniques; in particular, functional outcomes, setbacks, and the time needed before a return to productivity should be compared. These parameters were taken into consideration in our study design [8].

This study was planned as a case series. Our study sample of 13 patients was comparable to the study populations in recent papers in opponensplasty published by Al-Qattan, Park and colleagues, and Akram and colleagues [6, 7, 19].

Children tend to experience faster and more successful healing and can more easily adapt postsurgery; reports supporting these statements were published by Moehrlen and colleagues in 2009. Additionally, many authors recommend the use of different approaches in children; for example, many find the Huber transfer a more suitable option for opponensplasty in children. For these reasons, children younger than 10 years of age were not included in our study. The same principles apply for the elderly, who tend to have poor wound healing and are more difficult to re-educate. In addition, the return to productivity could not have been assessed in elderly patients [20, 21].

Patients with preoperative joint stiffness and hand ischaemia are especially prone to poor results and adhesion formation. Therefore, these patients were excluded. In our opinion, reconstructing a non-sensate hand would be pointless because, even after a successful transfer, functionality would not be restored. We excluded many patients with old brachial plexus injuries with insensate hands from our study for this reason. A similar point of view was adopted by Davis, the author of the chapter entitled "Principles of Tendon Transfers of Median, Radial, and Ulnar Nerves" in Green's Operative Hand Surgery, 7th edition [14].

When deciding on the mode of insertion in EIP opponensplasty, the following two factors served as a guide: the nerve injury and the length of the tendon. In the completely intrinsic minus thumb, we preferred triple insertions to actively restore abduction and passively produce internal rotation and flexion of the MP joint. The third insertion into the EPL was deemed unnecessary in cases with a functioning FPB. In two cases, the transferred EIP could not reach the third insertion site, and the third insertion was therefore omitted.

Many systems do not document the pattern of pinch, an important criterion that reflects the internal rotation component of opposition. In addition, the Kapandaji scoring system requires action of the FPL for the thumb to reach scores 7–10,

Fig. 7 Case 4 preoperation (left) and 18 months postoperation, with poor opposition (score of 1 according to our scoring system and a Kapandaji score of 2)

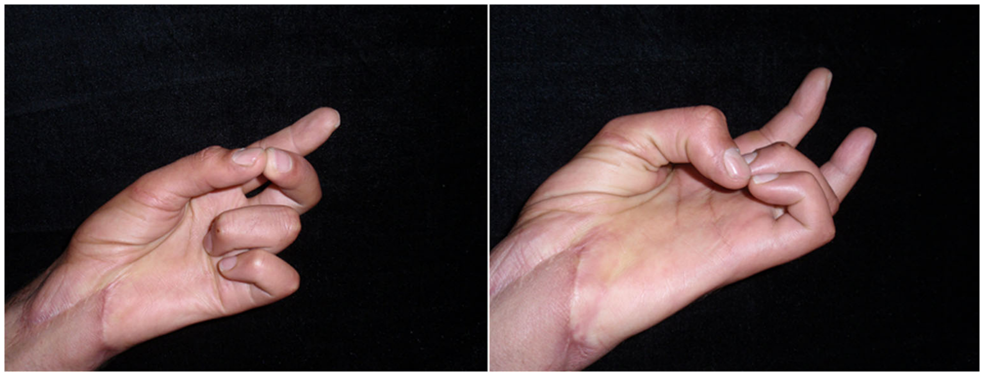

Fig. 8 18 months postoperation; 3A opposition (left), Kapandaji score of 6 (right)

rendering it less accurate for describing the results of opposition in cases of proximal median nerve palsies and in other cases with non-functional FPLs. The Mehta and Malivaya evaluation system, on the other hand, takes the pattern of pinch into consideration but lacks simplicity and is very difficult to apply. We also found that the Sundraraj and Mani system is not very informative, as it regarded reaching any fingertip as an excellent to good outcome, while we find that reaching the tip of the index finger does not constitute functional success. In fact, an arthrodesed thumb is still able to touch the tip of the index finger with index flexion [15, 17, 18].

Our system, however, fulfils these three criteria. It is informative; one can tell the exact position of the thumb during opposition, and hence, it is useful for comparing results. It is easy to apply. It is function-oriented, as it includes the pattern of the pinch, which reflects internal rotation. This new system should enable us to compare the different patterns of insertions with more discrete outcomes.

Our technique for EIP opponensplasty resulted in excellent outcomes in 92% of the patients, according to the classic scoring system. However, when analysing the results of our EIP opponensplasties using our evaluation system, only seven patients achieved the ideal thumb pulp to little finger pulp pinch (5A), two patients had scores of 5B, one patient had a score of 4A, one patient had a score of 4B, one patient had a score of 3A, and one patient had a score of 1. These results are superior to those in Burkhalter's original series, in which 88% of the surgeries had excellent to good results. However, AlQattan and Akram and coworkers achieved uniformly excellent to good results in their studies. Our one disappointing result was attributed to a poor choice of transfer, as the patient had a partial radial nerve injury, and he could barely extend his index finger against gravity. However, due to the small choice of available donors, we decided to use the weak indicis rather than sacrificing a second wrist extensor [5–7].

Whenever we used a triple insertion in a properly selected transfer, we achieved a 5A score. This was not the case when we settled for a double insertion; only three patients achieved full correction (all had a preoperatively functioning FPB). Hence, the key to full restoration of opposition is to address the following three components: abduction, internal rotation, and flexion. Therefore, the ideal evaluation system should consider these three components.

When the Kapandaji system was applied to our patients, three of the patients with proximal median nerve palsies achieved scores of 6, despite full restoration of all three components of opposition, with a 5A pulp-to-pulp pinch. In contrast, one patient scored 6 according to the Kapandaji system but lacked opposition and scored only 3A according to our system (Fig. 8). We believe that the discrepancy is the result of the fact that the Kapandaji system does not describe the pattern of pinch as does the more complex Mehta and Malivaya system. We included that particular component in our proposed system. Thus, our system is a modification of both the Mehta and Malivaya and Kapandaji systems.

Most published studies focus on functional outcomes and complications. However, the return to productivity after tendon transfer remains understudied. This fact and a large retrospective study published by Jaquet and coworkers in 2001 inspired us to include the return to productivity, which is the ultimate goal of surgery, in our assessment system [22].

Our study is not without limitations. The lack of a comparison with other techniques makes the study insufficient on its own to establish the superiority of EIP opponensplasty over other transfers. In addition, future studies should include larger sample sizes to enable comparisons of the different insertions in opponensplasty. Furthermore, patient satisfaction scores were not relied on in this study because many of our patients received multiple transfers and ancillary procedures that would have influenced patient satisfaction and their scores would not reflect their true satisfaction specifically with the opponensplasty. However, we believe that the first step to improvement of EIP opponensplasty is to establish an applicable evaluation system that can accurately assess opposition.

Conclusion

Although our work is inconclusive regarding the appropriate choice of insertion for EIP transfer, it provides a reasonable and reproducible evaluation system that allows fine tuning of the comparison of results that may be useful in future studies comparing different donor sites and insertions with regard to the restoration of opposition. Additionally, the new scoring system should be more informative when comparing nerve transfers to tendon transfers.

Compliance with ethical standards

Funding The authors did not receive any funding for the completion of this work.

Declaration of conflicting interests Omar Mohamed Nouh, Shaimaa Mostafa Gad, Youssif Ahmed Khashaba, Ashraf Abolfotooh Khalil, Ashraf El-Sebaie Mohamed, and Mostafa Ahmed Abo Elsoud declare that they have no conflicts of interest.

Ethical committee approval Ethical committee approval was obtained.

Informed consent Informed consent was obtained from all patients who were part of the study. The study included one minor, and informed consent was obtained from his parents. The consent form included details regarding the preoperative measures, the operative procedure, and the postoperative outcomes, including potential complications. Patients or their legal guardian (one patient) also consented to enrolment in the study and the publication of the results.

Patient consent Patients provided written consent for the use of their images.

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