Restoration of Forearm Supination by Combining Pronator Teres With Allogeneic Tendon

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Research Article

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Abstract

Background

Many solutions have been proposed in treating of forearm supination. Comparing with other supination function reconstructions, pronator teres rerouting is believed to be less effective. The aim of this study is to introduce a modified procedure, which avoids the shortness from previous attempts, and obtains good result.

Patients and Methods:

From 2015 to 2020, 11 patients have restored forearm supination by rerouting of the pronator teres weave sutured with allogeneic tendons. The average follow-up period was 17.5 months (12 to 24). The range of active supination at the final follow-up was recorded.

Results

Almost all patients acquired good supination range. The average active post-operative supination was 72.7° (60° to 80°) at the final follow-up. No complication was observed. All patients retained full range of pronation.

Conclusions

This study provides a modified supination function reconstruction with simple operating, fine results, low risks, and no affecting of pronation function. The use of allogeneic tendon makes up for the muscles with insufficient length, making it valuable to reconsider those rebuilding operations that were once considered unpromising by many.

Background

Palm upward position (supination) is key to performing activities of daily living toward craniofacial organs, such activities include eating, cleaning, applying make-up and browsing and using of mobile phones. Palm downward position (pronation) allows the performing of work activities associated with objects. However, particular jobs like waiters and quality controllers have higher demand of supination than others.

Elbow radial nerve injuries do not usually cause loss of supination, because bicep is a strong supinator. But biceps brachii can only produce the greatest force when the angle of elbow flexion is between 90 and 120°. Muscle strength decreases gradually as the elbow moves farther away from this angle [1]. When the elbow is at a 90° angle, supination strength is at its greatest, whereas supination strength decreases as the elbow approaches 0° due to the contribution of biceps brachii to the supination movement [2]. Meanwhile, the biceps generate most of their torque while in pronation, and may not produce supination beyond the neutral position of the forearm if not assisted by a functioning supinator [3]. For the reasons above, some patients who suffer from elbow radial nerve injuries without receiving special supination function reconstruction, complain about their insufficient supination function after treatment.

Many solutions have been proposed in treating of forearm supination dysfunction, yet none is believed to have the best outcome.

In our practice, an allogeneic tendon is woven into the distal end of pronator teres to increase its length, and the insertion is relocated thereafter. Then the supination function was effectively restored.

Patients And Methods

From 2015 to 2020, 11 patients with elbow radial nerve injuries underwent this surgery to improve forearm supination function. 8 males and 3 females at an average age of 41.2 (23 to 52) years old participated. All participants fit in the following criteria: received radial nerve anastomosis for 6 months to 2 years with no satisfactory supination; forearm supination played a major role in daily life or work; forearm pronation strength reached grade 5 on MRC muscle scale; complete passive forearm supination (mean 83°, 75° to 90°) can be achieved (Table 1); no special supination function reconstruction was received. Patients were assessed monthly for the first three months after surgery, thereafter twice annually (mean 17.5 months, 12 to 24). The range of active supination at the final follow-up was recorded.

Table 1
Summary of patients

Cases	Age (yrs)	Sex	Side	Passive pre-operative supination (°)*	Active post-operative supination (°)	Follow-up (mths)
1	33	M	R	80	80	20
2	52	M	R	85	75	12
3	50	F	L	75	60	24
4	45	M	L	90	80	18
5	23	M	R	90	75	24
6	36	F	L	80	70	12
7	37	M	R	80	65	24
8	33	M	L	90	80	12
9	44	M	R	75	70	17
10	51	M	R	80	75	13
11	49	F	R	85	70	16

*all the patients have no active pre-operative supination (0°)

Statistics

The increased active supination angle (the angular difference between pre- and post-operative active supination angle) were calculated. Then one-way ANOVA test was used to analyze the difference between our result, Aderson's[4], and Amrani's[5] work. Statistical calculation was performed with SPSS 24.0 software (Chicago, Illinois). The differences with a P value less than 0.05 were considered as statistically significant.

Surgical Technique

A short longitudinal incision is made at the radial palmar midforearm to expose the distal insertion of pronator teres (Fig. 1(a)). Then the distal pronator teres is released from the radius. An allogeneic tendon is woven into the distal end of pronator teres to increase its length (Fig. 1(b)). The tendon is pulled to the palmar ulna under flexor digitorum superficialis. Bypassing the ulna, the tendon is pulled back under the extensor digitorum muscle. Auxiliary ulnar incision is optional. Insertion is rebuilt at the original insertion of pronator teres (Fig. 1(c)). Before finishing the rebuilt with a bone rivet, it should be ensured that the tension of pronator teres can hold the forearm to about 45° supination with the elbow in 90° flexion. Among some patients, pronator quadratus and/or interosseous membrane should be released to achieve adequate supination. The sutures are removed 12 to 14 days after surgery. Two demountable over-elbow plasters are applied to keep the elbow at 90° and the forearm in maximum supination for three weeks. The patients are encouraged to start initiative non-confrontational supination after the plasters are removed. Weight-bearing exercises can be started 6 weeks after operation.

Result

No complications were observed. All patients retained full range of pronation. Almost all patients acquired good supination range (Fig. 2). The average active post-operative supination was 72.7° (60° to 80°) at the final follow-up. Most of our patients were factory workers, they were able to perform daily activities involving forearm supination such as hair combing, using of chopsticks and spoons, twisting handles, reading on books and phones and tightening screws.

The average supination improvemenet was 72.7 ± 6.47° (60° to 80°) at the final follow-up. The supination improvemenet in our study was significantly larger than Aderson’s study (37.27 ± 18.21°, n = 11, $p < 0.001$). There is no difference in supination improvemenet between our method and Amrani’s study (73.57 ± 6.33°, n = 14, $p = 0.855$).

Discussion

It was first proposed in 1981 by Sakellarides *et al.*[6] that by modifying the original pronator teres radius insertion to the opposite side to act as supination force, it has resulted in an average of 46° supination. However, the significance of such operation has been doubted over time by scholars. Strecker *et al.*[7] verified that the impact of pronator teres rerouting surgery on supination distinctly excels simple tendon lysis. Nevertheless, the research of Veeger *et al*. claimed that the effect of pronator teres rerouting restoring supination is equivalent to a tendon lysis.[8] Gschwind and Tonkin carried out their modified approach of a Z-shaped prolongation of pronator teres tendon followed by repairing it bypassing the posterior of radius, pronation strength is thereafter released, good postoperative result is obtained.[9] Although rebuilding of tendon insertion is avoided, due to relatively shorter tendon length, the improper handling of tensile strength can still occasionally affect pronation.[10, 11] The resistance to tensile load of scar-healing prolonged tendon is also comparatively weakened.

Although different operation results have been reported, a number of surgeons still adopt the pronator teres rerouting approach to restore supination, especially when wrist and finger extensions are simultaneously in need of rebuilding while flexor carpi ulnaris muscle or other muscles are selected for use. In most studies above, pronator teres run through interosseous membrane instead of subcutis to avoid adhesion. However, the interosseous membrane plays a key role in a series of ligaments which maintains the stabilization of forearm. Injuring interosseous membrane would affect longitudinal and transverse stabilization of forearm.[12] Incomplete interosseous membrane incision would result in entrapment of pronator teres. Improved supination from simply rerouting pronator teres through interosseous membrane is limited on account of windlass effect, making it ineffective in converting muscle force into supination force.[13] The operating area in such surgery involves more significant deep anatomical structure such as radial artery, radial nerve (above pronator teres), anterior interosseous artery, median nerve and ulnar artery (beneath pronator teres). These structures would get more unrecognizable among scarring soft tissue after primary surgery, increasing operational time and difficulty. Now, these problems can be avoided with our approach.

Pronator teres starts from medial epicondyle of humerus and the medial side coronoid process of ulna, crossing the forearm diagonally and inserting halfway down the lateral surface of the radius. Supinator takes its origin from lateral epicondyle of humerus and lateral side of ulna, ending at the upper volar palmar radius. The origin and termination of these two muscles are at close distance and respectively put radius in spinning motion around ulna in opposite directions. Therefore rerouting pronator teres as supinator is essentially duplicating the mechanism of supinator.

Van Heest *et al.*[13] meticulously underwent cadaveric studies about restoring of supination through pronator teres rerouting, comparing pronator teres insertions at 6 different positions: volar insertion, interosseous ligament insertion, dorsal insertion, native insertion after rerouting around the radius, volar insertion after rerouting around the radius, and 6 new positions 1cm shifted toward the near end of radius from their original positions. By studying the 12 insertions, the optimum supination is acquired when pronator teres is rerouted through an interosseous window and reinserted into its original insertion place or onto the volar surface of radius. The average active supination angle is at 47°, with no evident disparity of that with 1cm shifts toward proximal radius. This insertion is adopted in our method due to its relatively good supination.

Aderson *et al.*[4] transfered the tendon of flexor carpi ulnaris to the split tendon of brachioradialis with its bony insertion into the radial styloid. The average supination improvemenet was 37.27 ± 18.21°. Amrani *et al.*[5] corrected the pronation deformity in 14 children by rerouting the distal part of pronator teres dorsally to volarly through a window in the interosseous membrane and suturing to the proximal tendon. The average supination improvemenet was 73.57 ± 6.33°. Through statistical comparison, we found that average supination improvemenet of our results were significantly better than the former, and there was no significant difference from the latter. However, compared with Amrani's method, our method avoids damage to the structures between the ulna and radius, reduces the risk of surgery, and simplifies the procedure.

Conclusions

This work provides a modified supination function reconstruction with simple operating, fine results, low risks, and no affecting of pronation function. The use of allogeneic tendon makes up for the muscles with insufficient length, making it valuable to reconsider those rebuilding operations that were once considered unpromising by many.

Abbreviations

MRC
Medical research council; SPSS:Statistical product and service solutions

Declarations

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Authors’ contributions

SHF, HX, and XJH designed the study and performed the surgeries. DSL,JQJ, and LKJ collected and analyzed the data. DSL, JQJ, and LYM wrote the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets supporting the conclusions of this article are included within the article. The raw data can be requested from the corresponding author.

Ethics approval and consent to participate

This study followed the principles outlined in the Declaration of Helsinki, and approved by the Clinical Research Ethics Committee of the First Affiliated Hospital, College of Medicine, Zhejiang University (IIT 2015-0016). The participants provided written informed consent to participate in this research.

Consent for publication

The written informed consent for publication was obtained from all patients.

Competing interests

The authors declare that they have no conflict of interests related to this work.

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Figures

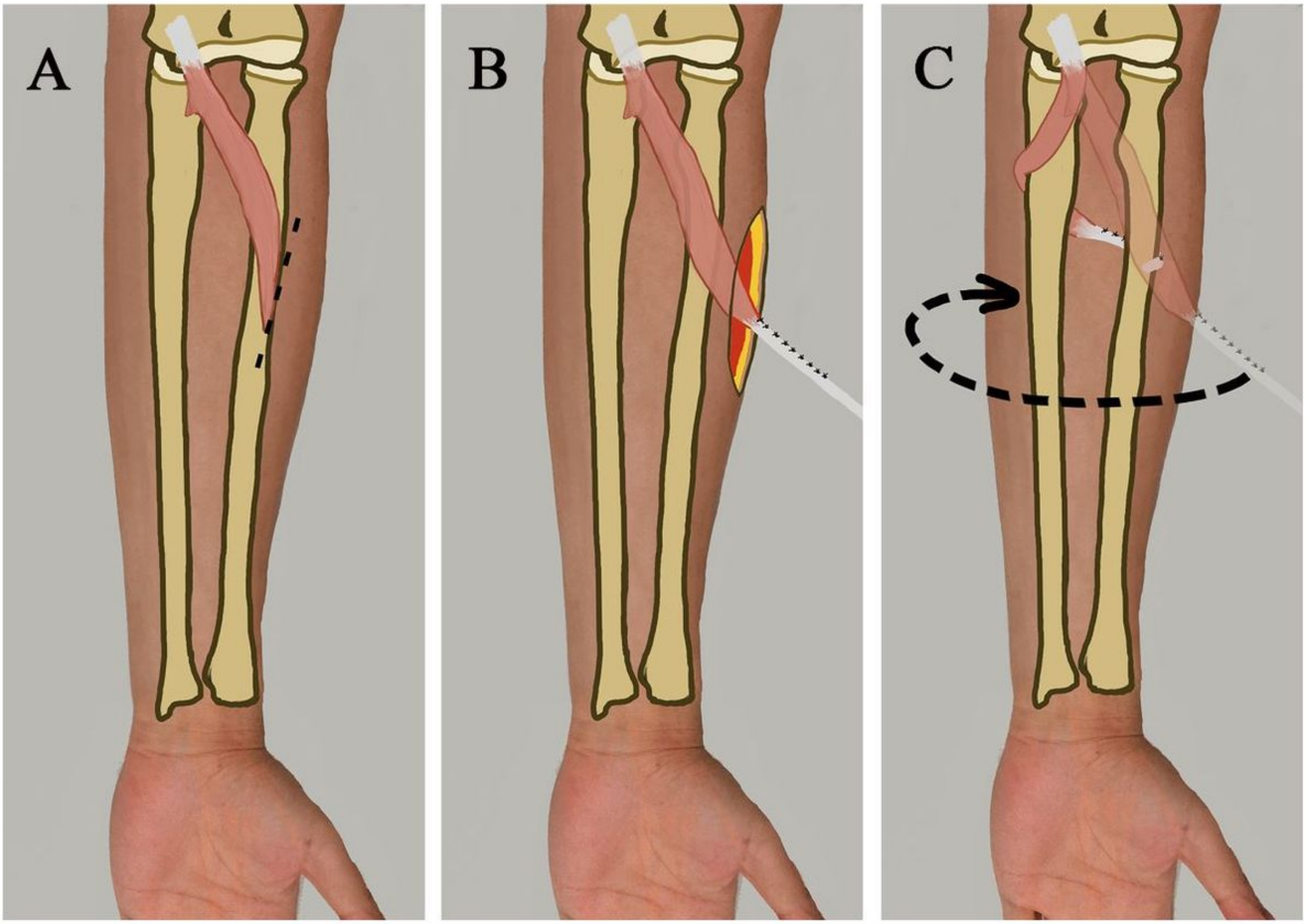

Figure 1

A short longitudinal incision is made to expose the distal insertion of pronator teres (a). The pronator teres is released and lengthened with an allogeneic tendon (b). The tendon is pulled to the palmar ulna under flexor digitorum superficialis. Bypassing the ulna, the tendon is pulled back under the extensor digitorum muscle(c).

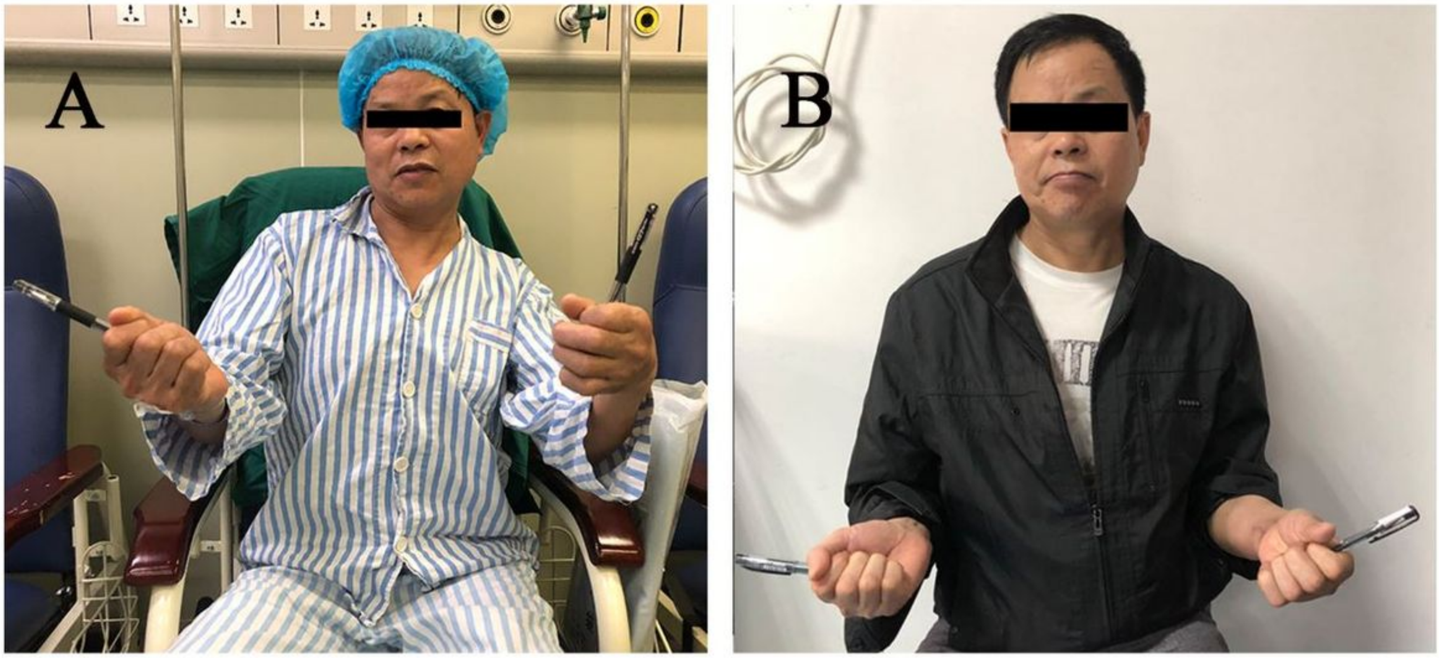

Figure 2

A 52 years old man with a pronation deformity after elbow radial nerve injury. Pre-operatively, the supination angle was 10° (a). Six months after operation, with 75° supination (b).