Active Voluntary Contraction of the Ruptured Muscle Tendon during the Wide-awake Tendon Reconstruction

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**Purpose:** The purpose of this study was to measure the active voluntary contraction distances of ruptured musculotendinous units during wide-awake tendon reconstruction surgery and to investigate the relationships between active contraction distance and the passive distraction distance and the time elapsed before reconstruction.

**Methods:** The passive distraction distance and active contraction distance of 36 tendons of 22 patients who underwent forearm tendon transfer or tendon graft during wide-awake surgery were measured.

**Results:** The passive distraction distance was significantly related to the active contraction distance of the ruptured musculotendinous unit ($r = 0.60, P < 0.05$). The passive distraction distance accounted for approximately half of the total excursion of the musculotendinous unit. There was no significant correlation between each distance and the time elapsed before reconstruction.

**Conclusions:** The passive distraction distance was significantly related to the active contraction distance of the ruptured musculotendinous unit in vivo during wide-awake surgery. Active musculotendinous unit contraction distance may be a useful index to evaluate ruptured musculotendinous unit degeneration and donor muscle function in standard tendon reconstruction. This study suggested that the advantages of the wide-awake approach were not just as a clinical tool but also as an in vivo research tool. (Plast Reconstr Surg Glob Open 2017;5:e1597; doi: 10.1097/GOX.0000000000001597; Published online 28 December 2017.)

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evaluating myostatic contracture in reference to the muscle elasticity by the passive distraction distance and the time elapsed before reconstruction. The purpose of this study was to quantify the active contraction distance of the ruptured musculotendinous unit during wide-awake surgery and to investigate its relationships to the passive distraction distance and the time elapsed before reconstruction.

**MATERIALS AND METHODS**

We started wide-awake tendon surgery from April 2011. A total of 36 tendons of 22 consecutive patients who underwent forearm tendon transfer or tendon graft during wide-awake surgery in our department from April 2011 to January 2016 were evaluated as a sample of convenience. The study group consisted of 15 women and 7 men with a mean age of 71 ± 12 years (range: 40–89 y). The dominant arm was affected in 16 patients. Fifteen patients underwent wide-awake local anesthesia no tourniquet (WALANT) technique using lidocaine–epinephrine, and seven of them who needed osteotomy or plate removal underwent ultrasound-guided selective sensory nerve block. A total of 22 ruptured tendons and 14 donor musculotendinous units for tendon transfer were targeted. The time elapsed before reconstruction was 1–48 months (median 3 mo). Table 1 lists the types of target musculotendinous units investigated. The cause of the tendon rupture was distal radioulnar joint osteoarthritis, rheumatoid arthritis, scaphoid non-union advanced collapse wrist, and distal radius fracture.

Tenolysis of the ruptured tendons was performed until the muscle-tendon junction was observed, and the musculotendinous unit was distracted continuously to improve myostatic contracture as much as possible. The ruptured musculotendinous unit was then distracted, and the passive distraction distance from the resting position to the maximum distal point was measured. Then, the patients were asked to grip and release their fingers with maximum power, and the voluntary ruptured musculotendinous unit contraction to the proximal side was observed. (See video, Supplemental Digital Content 1, which displays the ruptured musculotendinous unit. This video is available in the “Related Video” section of PRSGlobalOpen.com or at http://links.lww.com/PRSGO/A620.)

### Table 1. Target Muscle Tendons

| Twenty-five flexor | Eleven extensor |
|--------------------|-----------------|
| Tendon ruptures in zone 4 or 5 (old) | Tendon ruptures (old) |
| FPL | EDC |
| FDP | EPL |
| FDS | EDM |
| Donor site of tendon transfer or graft (fresh) | Donor site of tendon transfer (fresh) |
| FDS | EIP |
| PL | | |
| FCR | } |

### Video Graphic 1

See video, Supplemental Digital Content 1, which displays the ruptured musculotendinous unit. This video is available in the “Related Video” section of PRSGlobalOpen.com or at http://links.lww.com/PRSGO/A620.

![Video Graphic 1](image)

**Fig. 1.** The ruptured musculotendinous unit is distracted, and the passive distraction distance from the resting position to the maximum distal point is measured. The patients are then asked to grip and release their fingers with maximum power, and the active contraction distance is measured from the resting position to the maximum proximal point (see video, Supplemental Digital Content 1, which displays the ruptured musculotendinous unit. This video is available in the “Related Video” section of PRSGlobalOpen.com or at http://links.lww.com/PRSGO/A620).

The active contraction distance was measured from the resting position to the maximum proximal point (Fig. 1). The same measurement was performed at the donor site of both the tendon transfer and the tendon.
graft (See video, Supplemental Digital Content 2, which displays the musculotendinous unit of the donor site. This video is available in the “Related Video” section of PRSGlobalOpen.com or at http://links.lww.com/PRSGO/A621). In all procedures, 2 hand surgeons measured each distance. Whether there was a correlation between the passive distraction distance and the active contraction distance of the ruptured musculotendinous unit was investigated. In addition, whether these distances were affected by the time elapsed before reconstruction was also examined.

**Statistical Analysis**

All data are shown as means and standard deviations. Correlation coefficients between each of passive distraction distance, active contraction distance, and the time elapsed before reconstruction rupture were calculated. Correlations analyses were performed using Pearson correlation test. The level of significance was set at $P < 0.05$ for all analyses.

**RESULTS**

The active muscle contraction distance was measured in all cases during wide-awake surgery. The mean passive distraction distance of the forearm muscle tendon was $17.9 \pm 5.2 \text{ mm}$ (range: 10–30). The mean active contraction distance of the forearm muscle tendon was $18.6 \pm 7.4 \text{ mm}$ (range: 4–35). The passive distraction distance was significantly related to the active contraction distance of the ruptured musculotendinous unit (Pearson coefficient of correlation $r = 0.60$, $P < 0.05$) (Fig. 2). The results showed that the passive distraction distance accounted for approximately about half of the total excursion of the musculotendinous units.

When the musculotendinous units were divided into old ruptured and fresh donor-site areas, the passive distraction distance was significantly related to the active contraction distance of the old ruptured musculotendinous unit ($r = 0.71$, $P < 0.05$). On the other hand, the passive distraction distance was not related to the active contraction distance of the fresh donor site of the musculotendinous unit (Fig. 3).

There was no significant correlation between the passive distraction distance and the time elapsed before reconstruction. Similarly, there was no significant correlation between the active contraction distance and the time elapsed before reconstruction, but the active contraction distance of the flexor pollicis longus (FPL) tended to become small as the time elapsed before reconstruction increased (Fig. 4).

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**Video Graphic 2.** See video, Supplemental Digital Content 2, which displays the musculotendinous unit of the donor site. The site is distracted, and the passive distraction distance from the resting position to the maximum distal point is measured. Then, the patients are asked to grip and release their fingers with maximum power, and the voluntary ruptured musculotendinous unit contraction to the proximal side is observed. The active contraction distance is measured from the resting position to the maximum proximal point. This video is available in the “Related Video” section of PRSGlobalOpen.com or at http://links.lww.com/PRSGO/A621.
Case Presentation

A 70-year-old man had sustained a right distal radius fracture 12 years earlier. Open reduction and internal fixation with a volar nonlocking plate was performed in another hospital. He could not flex the thumb 7 years later and was not able to flex the index finger 12 years later and came to our hospital for a consultation. We had a diagnosis of the secondary flexor tendon rupture of the thumb index finger caused by the volar nonlocking plate. We performed tendon reconstruction and plate removal by WALANT technique and radial nerve superficial branch block. The flexor digitorum profundus (FDP) of the index finger and the FPL tendon

Fig. 3. A, The passive distraction distance is significantly related to the active contraction distance of the old ruptured musculotendinous unit. B, The passive distraction distance is not related to the active contraction distance of the fresh donor site of the musculotendinous unit.

Fig. 4. A, The passive distraction distance of the FPL tendon is not significantly related to the time elapsed before reconstruction. B, The active contraction distance of the FPL tendon is not significantly related to the time elapsed before reconstruction, but it tends to become small as the time increases. C, The passive distraction distance of the flexor digitorum profundus (FDP) tendon is not significantly related to the time elapsed before reconstruction. D, The active contraction distance of the FDP tendon is not significantly related to the time elapsed before reconstruction.
rupture were found. When we measured about the FPL musculotendinous unit during surgery, the active contraction distance was 14 mm and the passive distraction distance was 14 mm. We considered that this muscle was not available and performed tendon transfer from the flexor digitorum superficialis of the ring finger. Then, when we measured about the FDP musculotendinous unit of the index finger, the active contraction distance was 18 mm and the passive distraction distance was 22 mm. We considered that this muscle was available and performed tendon grafting. Active range of motion was complete during surgery. At 1-year follow-up, active and passive ranges of motion were maintained.

**DISCUSSION**

In tendon reconstruction, selection of the motor and suture tension is a key to success. It is well known that ruptured musculotendinous unit has decreased function and contractility of the muscles after a certain time. However, there have been no reports of the relationship between ruptured musculotendinous unit contractility and the time between rupture and reconstruction. After more than several months following rupture, the musculotendinous unit generally leads to myostatic contracture and muscle shortening. On the other hand, at the donor site of tendon transfer, which was just cut, the function and contractility of the muscles are retained.

However, whether the muscle contraction remains and how much muscular contraction can be performed are unknown. The intraoperative appearance or the view on magnetic resonance imaging provides a poor indication of muscle function. Further increasing muscle length increases its passive tension, but there is no clear relationship between passive tension and active muscle force production. Because there is no clear index, predicting the active contraction distance has only been possible with reference to the passive distraction distance of the musculotendinous unit. However, Nakamura and Katsuki stated that the intraoperative muscle passive distraction does not definitely reflect the excursion distance after tendon reconstruction based on the outcome of tendon grafting. Lieber stated that muscle excursion cannot be felt during surgery, but we can check muscle excursion during wide-awake surgery. This study demonstrated that passive musculotendinous unit distraction distance was significantly related to active musculotendinous unit contraction distance of the ruptured musculotendinous unit in vivo during wide-awake surgery. This suggests that the passive musculotendinous unit distraction distance predicts muscle contraction and will help predict the outcome of tendon reconstruction after several months have passed. There was no correlation in fresh tendon transfer, probably because of the small number of cases, which was a limitation of this study.

Moreover, the correlation between these distances and the time elapsed before reconstruction was also examined. There was no significant correlation between each distance and the time. Only the active contraction distance of the FPL tended to become small as the time increased. Whether muscle contraction becomes small as the time increases is considered to depend on the classification based on muscle shape. For example, according to the classification by muscle shape, the FPL is a semipennate muscle, and the FDP is a unipennate muscle.

The usefulness of wide-awake surgery has been widely reported. Furthermore, with wide-awake surgery, one can obtain new knowledge. The results of this study were obtained from wide-awake surgery, and it was found that it is easy to predict the outcome with wide-awake tendon reconstruction. However, wide-awake surgery cannot be performed in all cases, so that it would be necessary to predict the active contraction distance from the passive distraction distance even under general anesthesia.

The limitations of this study include the variations of the musculotendinous units and the small study group. We plan to increase the number of cases in future investigations. And the limitation of this method was manual measuring and not blinded, but the measured value accorded among 2 surgeons every time.

**CONCLUSIONS**

From the results of this wide-awake surgery study, active musculotendinous unit contraction distance may be a useful index to evaluate ruptured musculotendinous unit degeneration and donor muscle function in standard tendon reconstruction. This study suggested that the advantages of the wide-awake approach were not just as a clinical tool but also as an in vivo research tool.

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