Optimum Procedure To The Flexor Tendon Repair During Blocking Finger Exercise

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Disclosures:

Introduction: Recovery of active finger flexion and prevention of stiffness of interphalangeal joint remains an issue following flexor tendon injuries. Because the results of immobilization after flexor tendon repair were unsatisfactory, early active finger motion has been used to obtain effective tendon gliding with minimal adhesions.

Blocking exercise (BE) has been performed as a useful procedure after flexor tendon repair in clinical practice. The proximal interphalangeal (PIP) joint is fully extended when the distal interphalangeal (DIP) joint is actively flexed (1) (Figure 1). During this procedure, the motion of the flexor digitorum superficialis (FDS) tendon is blocked while the maximum gliding of the flexor digitorum profundus (FDP) tendon is promoted (2). As a result of this, relative displacement between FDP and FDS is facilitated to gain tendon gliding and to inhibit adhesions. Although the BE has been known as an effective treatment after tendon repair, a risk of re-rupture is worried when an excessive force is loaded on the suture site. The compression may add gliding resistance of the FDP tendon around A4 pulley, which may eventually increase the force to the tendon during DIP joint motion.

The purpose of this study was to investigate the FDP tensile loading in applying incremental pressure on the palmar side of the middle phalanx as simulated BE procedure. It would provide better understanding of flexor tendon rehabilitation to discuss safety and efficacy of the BE procedure after tendon repair.

Methods: Six cadaveric middle fingers from 1 female and 5 male were studied. Mean age was 85 years (range, 82-93yrs). The specimens had no evidence of previous injury, operations, or severe deformity by visual inspection. The middle finger was cut at the shaft of the metacarpal bone. The digital extensor tendon, and FDP and FDS tendon was cut at the PIP joint, and at the wrist joint, respectively. The whole flexor tendon sheath of the finger was intact to remain the pulley system. The PIP was fixed in 0° extension by passing Kirchner wires 1.6mmϕ between middle phalanx and metacarpal bones. The metacarpophalangeal (MP) joint was also straightened to eliminate the effect of the joint angle. The specimens were placed on a special fixation jig by Kirchner wires of 1.0mmϕ (Figure 2). The proximal end of the FDP tendon was mounted on a materials testing machine(STA-1150, ORIENTEC, Tokyo, Japan; capacity 500N, accuracy ±0.2%FS) to assess FDP tendon loading. 0.5N was applied to the tip of the finger as simulated the tensile force of the extensor tendon.

Three markers of 1mmϕ were placed on the lateral aspect of the center of PIP and DIP joint, and distal phalanx. Another maker of 1mm in diameter was placed on the FDP tendon at the proximal of the A1 pulley to measure the FDP tendon gliding distance. The lateral aspect of the specimen was recorded by using the digital video camera (resolution 1920×1080 pixels, HDR-XR520V, Sony, Tokyo, Japan) during the FDP tendon was pulled proximally at 20 mm/min between 0° and 60° flexion of the DIP joint (Figure 2 and 3).

To simulate the compression force of blocking the PIP joint motion, weights from 0N to 30N were loaded on the skin surface of the palmar aspect at the middle phalanx in 5N steps. The compression force was applied as shown Figure 2 and 3. The recorded video data was analyzed by software (Dartfish software ver.4.0, Dartfish Japan, Tokyo, Japan) and calculated the tensile load of the FDP tendon during the DIP joint movement flexion from 0° to 60° in 10° steps.

Results were expressed as a mean ± standard deviation (SD). Repeated measurement two-way analysis of variance with post-hoc Tukey test was used for the comparison of the tensile force between DIP joint angle and compression force. Statistical testing was performed using SPSS 17.0 software (SPSS Inc., Chicago, IL). All significance levels were set as α=0.05. In addition, tensile force of the 10N to the flexor tendon is known as 1mm gap is begun to occur at the tendon suture site by 4-strand repair (3). Therefore, the 10N was used as a safety reference during the procedure. This study was approved by our institutional review board (IRB).

Results: Table 1 shows the data of the tensile loading of the FDP tendon in each compression force (0N-30N) and DIP flexion angle (0°-60°). As increasing the DIP joint angle, the tensile loading was increased in each compression force (p<0.01) (Table 1). In the 50° and 60° DIP joint flexion, the tensile loading was over the 10N (Table 1). Figure 4 shows the curves of the tensile loading in each compression force and DIP flexion angle. Although the tensile loading was statistically increased from 20° flexion in the DIP joint (p<0.01) (Figure 4), the loading to the FDP tendon was maintained less than 10N at the 10N compression of the
50° DIP flexion. The average tendon gliding distance was 1.3±0.1mm in 10° steps of the DIP joint flexion.

**Discussion:** As simulated BE procedure, we measured the tensile load to the FDP tendon in applying incremental compression force. Regarding repaired flexor tendon, less than 10N is acceptable tensile load to prevent 1mm gap when 4-strand suture was preformed (3). The 1mm gap is known as a value which leads to failure of the tendon repair after surgery (4). In this study, the tensile loading did not exceed the 10N up to the 40° flexion of the DIP joint in any compression force. The adhesion should be prevented during tendon healing after the repair. It has been reported that 3 to 5 mm tendon gliding prevents the adhesion of the flexor tendon after tendon repair (5). In this study, 1.3 ±0.1mm gliding of the FDP tendon was generated in the 10° steps of the DIP joint flexion. Therefore, our results suggested that the BE procedure might be safety and effective until 30° to 40° DIP joint flexion to prevent the gap and adhesion by achieving about 3 to 5 mm gliding of the FDP tendon.

As a limitation of this study, the tensile loads of the normal tendon was demonstrated during BE procedure. Future study might be needed, but our data provided a useful data in applying the clinical practice.

**Significance:** We demonstrated the tensile load to the FDP tendon in applying incremental compression force as simulated the blocking finger exercise, suggesting that within the tensile load of 10N the exercise might be safety and effective until 30° or 40° DIP joint flexion to prevent the gap by achieving 3 to 5 mm gliding of the FDP tendon.

**Acknowledgments:** This study was funded by Sapporo Medical University.

**References:**

![Figure 1. Blocking Exercise. PIP joint is fully extended when DIP joint is actively flexed. Motion of FDS tendon is blocked while gliding of FDP tendon is promoted.](image)
Figure 2. Device for measurement of tensile loading on FDP tendon as simulated BE procedure. Motion of DIP joint was also recorded by a digital video camera.

Figure 3. Detail of testing apparatus. Middle finger was set to the wooden jig, and FDP tendon was pulled by testing machine. Compression force (0-30N) was applied at the palmer side of middle phalanx. 0.5N was applied to the finger tip as simulated the force of extensor tendon.
Table 1. Tensile loading of the FDP tendon during BE procedure (mean (SD)).

<table>
<thead>
<tr>
<th>DIP flexion angle</th>
<th>0N</th>
<th>5N</th>
<th>10N</th>
<th>15N</th>
<th>20N</th>
<th>25N</th>
<th>30N</th>
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<tr>
<td>10°</td>
<td>0.8(0.3)</td>
<td>0.9(0.4)</td>
<td>1.0(0.4)</td>
<td>1.1(0.4)</td>
<td>1.1(0.4)</td>
<td>1.2(0.4)</td>
<td>1.3(0.4)</td>
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<tr>
<td>20°</td>
<td>1.5(0.5)</td>
<td>1.8(0.5)</td>
<td>2.2(0.7)</td>
<td>2.4(0.6)</td>
<td>2.6(0.6)</td>
<td>2.9(0.7)</td>
<td>3.2(0.7)</td>
</tr>
<tr>
<td>30°</td>
<td>2.5(0.7)</td>
<td>3.2(0.6)</td>
<td>3.7(0.8)</td>
<td>4.2(0.7)</td>
<td>4.7(0.8)</td>
<td>5.1(0.8)</td>
<td>5.8(0.7)</td>
</tr>
<tr>
<td>40°</td>
<td>4.1(1.3)</td>
<td>5.2(1.2)</td>
<td>6.0(0.9)</td>
<td>6.6(1.0)</td>
<td>7.4(0.9)</td>
<td>8.1(0.8)</td>
<td>9.3(0.9)</td>
</tr>
<tr>
<td>50°</td>
<td>7.2(2.6)</td>
<td>8.8(2.2)</td>
<td>9.9(1.8)</td>
<td>10.9(1.7)</td>
<td>11.7(1.5)</td>
<td>12.7(1.3)</td>
<td>14.7(1.5)</td>
</tr>
<tr>
<td>60°</td>
<td>13.0(3.9)</td>
<td>14.8(3.6)</td>
<td>16.7(3.2)</td>
<td>18.0(3.2)</td>
<td>19.5(3.2)</td>
<td>21.4(2.7)</td>
<td>23.2(2.6)</td>
</tr>
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</table>

Comparison of joint angle and compression force. a, b, c, d, e indicated significantly difference of tensile load between 10°, 20°, 30°, 40°, 50° DIP flexion, respectively, in each compression force (p<0.01). Colored box indicated up to 10N (Safety zone).

![Chart](chart.png)

Figure 4. Curves of tensile load to the FDP tendon in each compression force and DIP flexion angle. Safe zone is indicated as gap limit of 4-strand suture tendon (10N).

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