Flexor Digitorum Profundus Reconstruction: A Cadaveric Comparison of Three Techniques

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Disclosures:

Introduction: Flexor digitorum profundus (FDP) avulsion injuries are relatively common. Current repair strategies are not strong enough to withstand active motion rehabilitation post-operatively. Active motion protocols are warranted to prevent complications from adhesions and joint contractures, which lead to poor clinical outcomes. The purpose of this study is to investigate if including the volar plate in FDP reconstructions results in a stronger construct than current techniques.

Methods: Eighteen fresh-frozen cadaveric fingers were divided into three reconstruction groups (N = 6 each). The first repair technique was comprised of two DePuy Mitek (DePuy Mitek, Inc., Raynham, MA) micro suture anchors only (A). The second utilized a volar plate reconstruction alone (VP). The third group was a hybrid of the first two, combining a single DePuy Mitek micro suture anchor with volar plate augmentation (AVP). A 1.6mm k-wire was placed through the bone distal to the repair and u-shaped for placement in the loading fixture mounted on an Instron 1321 biaxial servohydraulic test machine (Instron Corp., Canton MA) retrofitted with MTS TestStar™ II digital controller (MTS Corp., Eden Prairie MN). (Figure 1) A small black bead was glued onto the bone distal to the repair but proximal to the k-wire, and another bead was glued onto the tendon proximal to the repair to allow for optical analysis of repair gapping. After repair, the specimens were loaded cyclically from 2 to 15 N at 5 N/s, for a total of 500 cycles. Cylindrical testing simulated passive motion loading and followed a previously published protocol. [1] A video camera (Panasonic PV-GS35 Digital Palmcorder, Panasonic Corporation of North America, Secaucus NJ) captured images of the repair and gap formation was assessed every 100 cycles using NIH Image-J freeware (National Institutes of Health, Bethesda, MD). Clinical failure was defined as gapping greater than or equal to 3mm. After cyclic testing, specimens were tested with a one-time load to failure at a rate of 0.33 mm/s until physical failure defined as hardware failure, suture breakage, or volar plate avulsion. Video images were continuously captured during load to failure and used to determine initial repair stiffness from 0 to 30N load versus gapping and the load at clinical failure (3mm gap). Data was analyzed via mixed model ANOVA followed by Tukey-Kramer post-hoc pairwise comparisons with statistical significance set at p values less than 0.05.

Results: One VP specimen was excluded from the study when it was accidentally overloaded during setup. No samples physically failed during cyclical testing. Throughout cycling, the A group experienced significantly more gapping than the VP and AVP groups (p<0.0001). (Table 1) No significant difference in gapping was detected between VP and AVP groups throughout cycling (p>0.91). The amount of gapping after cycling for all VP and AVP specimens was less than 3mm. Three of the A specimens exceeded 3mm during cycling. Thus, a measure of the load at clinical failure was absent for these three specimens from the following load to failure test though stiffness and the load at physical failure were measured. During load to failure, no difference was detected in initial stiffness between repair groups (p>0.32). (Figure 2) The load at clinical failure (3mm of gapping) for the A group was statistically lower than VP and AVP (p<0.005), while no difference was detected between VP and AVP (p>0.44). Load at physical failure for the A group was significantly lower than for VP and AVP (p<0.0001). No difference was detected between VP and AVP in the load at physical failure (p>0.87). All reconstructions involving an anchor failed by suture rupture at the suture-anchor interface. All VP specimens failed by volar plate avulsion. The k-wire for two AVP specimens broke through the bone before physical failure of the repair could occur and were therefore not a part of the above analysis of load at physical failure. Remaining AVP samples failed first by suture rupture at the anchor followed by volar plate avulsion.

Discussion: Biomechanical literature demonstrates that current reconstruction strategies for FDP zone 1 avulsions are not strong enough to withstand active digital motion post-operatively. Accounting for increased friction from edema [1] and decreased repair strength secondary to biology of healing [2], the estimated minimal strength for a tendon reconstruction is approximately 75N to comfortably allow for active motion rehabilitation. The two most used repair techniques - the dorsal button technique and the two suture anchors technique - physically fail at one time loads of approximately 40N and 70N[3], respectively. The volar plate is a stout, sturdy structure in proximity to the injured tendon that affords an additional fixation site to strengthen the repair. In our study, incorporating the volar plate into reconstructions increased the mean load to physical failure to 150N during one time load to failure. This is significantly stronger than current repair strategies. During failure testing, however, 3mm of...
gapping was reached at approximately 50 N, which means that the constructs failed by our clinical definition before the active motion threshold of 75 N. Nevertheless, in our cyclical testing that mimicked passive rehabilitation, augmentation with the volar plate resisted clinically detrimental gapping as compared to the two suture anchors[4]. Interestingly, using a suture anchor in combination with volar plate augmentation did not offer any significant advantage compared to volar plate augmentation alone.

**Significance:** By including the volar plate in zone 1 FDP reconstructions, significantly higher loads can be withstood compared to the current techniques in one-time load to physical failure testing, bringing us one step closer to developing a technique that may be able to withstand active, early motion rehabilitation. Furthermore, our data demonstrates that FDP reconstruction with the volar plate is a gap-deterring technique. These are exciting findings with strong clinical implications for surgical practice.

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**References:**

**Figure 1:** Typical set up for testing.
**Figure 2:** a) Initial stiffness of load versus repair gap evaluated from 0 to 30N, b) Load at clinical failure defined as 3mm of gapping or as the peak load if physical failure occurred first, c) Load at physical failure defined as the highest load associated with either suture breakage or volar plate avulsion. A - Anchors only, VP - Volar Plate only, AVP - Anchor + Volar Plate.

**Table 1:** Gapping of repair groups at 2N during cyclic loading. A - Anchors only, VP - Volar plate only, AVP - Anchor + Volar plate. Values reported as mean (sd).

<table>
<thead>
<tr>
<th>Gap (mm)</th>
<th>A</th>
<th>VP</th>
<th>AVP</th>
</tr>
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<tbody>
<tr>
<td>After 1st Cycle</td>
<td>1.6 (0.4)</td>
<td>0.9 (0.2)</td>
<td>1.0 (0.2)</td>
</tr>
<tr>
<td>After Last Cycle</td>
<td>3.2 (0.7)</td>
<td>1.8 (0.3)</td>
<td>1.8 (0.1)</td>
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