Simulated Distal Interphalangeal Joint Fusion of the Index and Middle Fingers in 0° and 20° of Flexion: A Comparison of Grip Strength and Dexterity

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Purpose To evaluate dexterity and grip strength after simulated distal interphalangeal (DIP) joint fusion of the index and middle fingers in varying degrees of flexion.

Methods Forty-six right-handed subjects performed grip and dexterity testing using the Grooved Pegboard Test in positions of index finger 20° flexion or full extension, middle finger 20° flexion or full extension, and unrestricted index and middle finger DIP joint motion (control). Simulated fusion was performed with the use of custom-molded thermoplastic orthoses.

Results Index finger dexterity scores were improved when the DIP joint was splinted in 20° compared with full extension. There was no significant difference in the middle finger dexterity when comparing 20° flexion with full extension. In either position, dexterity scores were higher (lower performance) for the index finger than for the middle finger, showing a greater interference to dexterity with splinting the index finger DIP joint. Mean grip strength was unaffected by middle finger DIP joint position, whereas splinting of the index finger in full extension resulted in reduced grip strength.

Conclusions Because positioning the middle finger DIP joint in either extension or 20° of flexion did not significantly affect grip strength or dexterity, other considerations such as appearance can be given priority. For the index finger, however, positioning the DIP joint in 20° of flexion may improve grip strength and dexterity over positioning it in neutral. (J Hand Surg Am. 2014;39(10):1986–1991. Copyright © 2014 by the American Society for Surgery of the Hand. All rights reserved.)

Type of study/level of evidence Prognostic I.

Key words Arthrodesis, fusion, distal interphalangeal joint, dexterity, flexor digitorum profundus.

Arthrodesis of the finger distal interphalangeal (DIP) joint is a common treatment for osteoarthritis,1 gout,2 psoriatic arthritis,3 and post-traumatic arthritis. Of all arthrodeses performed in the upper extremity, DIP joint fusions are well tolerated and impart the least detriment to hand function, which is supported by the finding that functionally only 15% of digital total active motion occurs at the DIP joint.4 Mechanical testing has shown that after simulated DIP joint fusion of the index and middle fingers, there was a 20% to 25% reduction in grip strength when compared with prefusion values.5 Fusion in a more flexed posture may decrease the tether of the flexor digitorum profundus tendon, thereby decreasing the quadrigia effect and potentially resulting in a smaller impact on grip strength.6

The purpose of this study was to compare simulated DIP joint fusion in full extension and 20° of flexion. Custom-molded thermoplastic orthoses were used to simulate the fusion. The fingers chosen for this study were the index and middle fingers, because they

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constitute (along with the thumb) the precision manipulation unit of the hand.\textsuperscript{6} We hypothesized that fusion in 20\textdegree of flexion is less detrimental to manual dexterity and grip strength when compared with fusion in full extension.

**MATERIALS AND METHODS**

Forty-six volunteers were studied (19 men, 27 women). The average age was 44 years (range, 35–61 y). All subjects were right-handed, and only the dominant hand was included in the study. All participants were healthy with no history of trauma, loss of motion, or neurological disorder that could affect hand function. The study was approved by our institutional review board, and informed consent was obtained from each subject. Materials included a grooved pegboard (Fig. 1) with 25 metal pegs (Lafayette Instrument Company, Inc, Lafayette, IN), custom-molded thermoplastic digital orthoses of the DIP joint, a stopwatch, and a grip manometer. Manual dexterity was assessed using the Grooved Pegboard Test,\textsuperscript{7} which is a test of motor performance commonly used as a component of several neuropsychological assessment batteries. Each participant is timed for placing 25 pegs, one at time, into the receptacles. Because the pegs must be rotated into position to be successfully placed, this test adds a dimension of complexity not found in motor tasks such as the Purdue Pegboard Test\textsuperscript{8} and thus is a sensitive instrument in detecting variations in the speed of motor function.

Subjects performed the Grooved Pegboard Test first without the use of digit immobilization, then with the DIP joints immobilized in 20\textdegree of flexion, and finally with the DIP joints immobilized in full extension using small custom-molded thermoplastic orthoses covered with a self-adherent wrap (Coban, 3M, St. Paul, MN). The orthoses were applied to the dorsum of the fingers over the distal and middle phalanges with circumferential adherent wrap (Fig. 2). Each test was timed and scored as the sum of the time in seconds to complete the test, number of pegs dropped, and number of pegs successfully placed in the holes.

Grip strength was measured with a Jamar dynamometer (Baseline Hydraulic Hand Dynamometer, FEI, White Plains, NY) set at the second station with the arm at the side, the elbow at 90\textdegree of flexion, and the forearm in neutral rotation. Patients were instructed to maximally squeeze the dynamometer 3 times, with a rest period of 30 seconds between attempts. The average of the 3 attempts was used for analysis.

Measurements of grip and dexterity were first done without the use of orthoses on both right and left sides to serve as individual controls. Next, grip strength was recorded sequentially for each of the 4 finger-orthosis combinations (index 0\textdegree, index 20\textdegree, middle 0\textdegree, middle 20\textdegree). Adjusted dexterity and grip were calculated by subtracting the baseline unsplinted measurements from the splinted measurements in order to control for individual differences.
Power calculation

We considered grip strength and dexterity scores (derived from the pegboard time) dependent variables. For power analysis, we used mean maximum grip strength of 28 kg for women and 47 kg for men across all age groups. The mean pegboard time reference values for subjects aged 40 to 49 is 64 seconds (SD, 7) and for subjects aged 50 to 59, 68 seconds (SD, 9). In order to achieve a power of 0.80 with an alpha level of 0.05, a sample size of 46 subjects was adequate.

Data analysis

This analysis included 2 independent variables: the finger splinted and the position of splinting. A 2 × 2 repeated measures analysis of variance was used for statistical analysis. Significant interaction terms were decomposed by examining simple main effects, which is examining the effect of one variable at each level of the other variable separately. All univariate analyses were evaluated using the Greenhouse-Geisser epsilon correction for lack of sphericity. A significance level of .05 was used.

RESULTS

Each subject successfully placed all 25 pegs in the holes. The detailed results are presented in Figures 3 and 4. Adjusted dexterity scores for the index and middle fingers are presented in Figure 3. The index finger dexterity score was significantly lower (better dexterity) when the DIP joint was splinted in 20° compared with full extension (P = .001). For the middle finger, however, no significant difference in dexterity scores were seen when splinting in 20° versus full extension. In both positions, dexterity scores were higher (lower performance) for the index versus the middle finger, showing a greater interference to dexterity with splinting the index DIP joint.

Mean adjusted grip strength and adjusted grip percent (relative to left side) were different for the index finger than for the middle finger. As shown in Figure 4, strength was largely unaffected by splinting the middle finger in either position. In contrast, splinting the index finger DIP joint in extension resulted in a reduction of strength compared with splinting in flexion (P < .005).

DISCUSSION

Arthrodesis is a common treatment for symptomatic arthritis of the DIP joints for patients who have failed conservative treatment. The goal of a successful arthrodesis is a solid bony union in the proper alignment; however, “proper” is not well defined, and the available data (Table 1) for choosing optimal fusion position are not based on objective studies of hand function. According to Carrol and Hill, the DIP joint should be fused in 25° of flexion to permit maximum flexion but can be amended to fit the patients’ need in specialized situations. Amadio and Shin advise that the position for DIP joint arthrodesis of the finger should be between 0° and 5° for all fingers other than the thumb. With the growing use of headless compression screws to obtain union and permit early motion, some authors are favoring DIP joint arthrodesis in full extension, which is
dictated by the technique. In addition, fusion in full extension is often desired by certain patients who feel that it is more aesthetically pleasing. Conversely, patients with certain vocational and/or recreational activities may benefit from fusion in a more flexed posture to maximize function. This is often seen in musicians, handle-holding athletes, and individuals who work with various tools requiring fine manipulation.

In our study, dexterity scores were better for simulated middle finger fusion versus index finger fusion in either position. We believe this is because the index finger is innately more dexterous than the middle and is used more during the task tested. When the index finger was not splinted, the subjects were able to perform the tasks more naturally and, therefore, had the lowest dexterity score (better performance). They were able to compensate for the loss of the neighboring middle finger’s DIP joint motion. Splinting the index finger imparted more demand on the middle finger, which is typically less involved in routine pinching, hence the lower dexterity scores.

Grip strength decreased significantly when the index finger was immobilized in full extension compared with immobilization in 20° of flexion. These results could in part demonstrate the effect of quadrigia. The index finger, even though typically thought of as having an independent flexor digitorum profundus (FDP) muscle belly, can have connections to the more ulnar FDP tendons. The connection can take the form of an oblique tendinous band between the middle finger FDP tendon proximally to the index FDP distally or simply synovial interconnections at the level of the carpal tunnel. With the index finger DIP joint held in full extension, the tethering effect on the more ulnar tendons is maximized, resulting in restricted flexion of the middle, ring, and little fingers and diminished grip strength. Conversely, with the index DIP joint splinted in flexion, the other portions of the FDP muscle become more lax and can account for the increased grip strength relative to full extension. Another possible explanation for better grip strength with the index DIP joint in 20° flexion is that in this position, the index finger wraps itself more stably around the dynamometer handle, whereas with DIP joint in 0°, the finger’s grip on the device is less secure.

<table>
<thead>
<tr>
<th>Study</th>
<th>Fixation Technique</th>
<th>Position of the Arthrodesis</th>
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<tbody>
<tr>
<td>Kocak et al, 2011</td>
<td>Herbert screw</td>
<td>10°</td>
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<tr>
<td>Ruchelsman et al, 2010</td>
<td>Percutaneous headless compression screw</td>
<td>≤ 10°</td>
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<tr>
<td>Song et al, 2012</td>
<td>Acutrak screw</td>
<td>12° (range, 0°—20°)</td>
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<tr>
<td>Ishizuki and Ozawa, 2002</td>
<td>Minimal invasive Herbert screw</td>
<td>0°</td>
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<tr>
<td>Konan et al, 2013</td>
<td>Acutrak screw</td>
<td>≤ 10°</td>
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<tr>
<td>Burton et al, 1986</td>
<td>Kirschner wires</td>
<td>10°—20°</td>
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<tr>
<td>Lewis et al, 1986</td>
<td>Kirschner wires (tenon method)</td>
<td>15°</td>
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Grip strength was unaffected by the position of simulated fusion in the middle finger. We cannot explain this finding on anatomical basis. Possible explanations include that the amount of finger flexion restriction (and thus quadrigia effect) is almost identical whether the joint is in 20° flexion or full extension, thus escaping detection by grip strength measurements owing to its small magnitude. Second, fatigue may play a role in mitigating a possible difference between long finger 0° and 20° grip testing, because subjects, by the time we measured their middle finger at 20°, had grasped the dynamometer maximally 9 times. Third, a possible difference in grip strength due to quadrigia between 0° and 20° may still exist with grasping small objects versus larger objects, and this should be taken into account while interpreting our results.

Fourth, blocking a digit from full flexion may result in increased strength measurements in other fingers, thus negating the effect of the blocked finger on the total grip strength. The authors suggested it to be the result of “variability in the ability of the subject to grip the measuring instrument as hard as possible or, possibly, some error in the accuracy of the instruments, despite regular calibrations.” And finally, as the same authors suggest, less developed interconnections between the muscle bellies of the ulnar 3 FDP tendons may allow some independent motion and less impact on grip strength with individual middle finger splinting. Further anatomical studies are required to characterize the interconnections between the FDP tendons proximal to the lumbrical insertion.

Our data suggest that fusion of the middle finger DIP joint in either full extension or 20° does not significantly affect grip or dexterity. Other considerations such as appearance may, therefore, be given priority. In addition, arthrodesis of the index finger in mild flexion may improve patients’ grip strength as well as dexterity over arthrodesis in full extension. It is reasonable to assume that a stable pain-free fusion would improve those measures over performing the test with a painful, arthritic joint. However, this was not addressed in our study because only normal subjects were included.

Limitations of this study include simulating fusion of the DIP joints with the use of custom-molded thermoplastic orthoses. We observed that splinted DIP joints were not completely rigid and did demonstrate small amounts of angulation with forced pinch. This slight movement within the orthosis may have lessened the impairment as compared with a solid fusion. Also, elastic tape was used over the orthosis, which is not similar to the grip of the skin and might interfere with tactile sensibility and contribute in part to the diminished performance in the dexterity test. Furthermore, disorders requiring DIP joint arthrodesis are often associated with adjacent joint impairment. These factors were not considered in this study. Another weakness of this study was that the testing procedure was not randomized. Each subject was tested in the same order. Learning could have confounded our results contributing to the observed improved dexterity seen in the third and fourth measurements as well as fatigue effect.

Another drawback is that only one functional dexterity test was used, which did not include the use of real-life objects.

REFERENCES


