INTRODUCTION

Fusion of finger interphalangeal joints is commonly indicated in the treatment of diseases such as osteoarthritis, gout, and scleroderma. The surgery provides a painless stable joint [1] but obviously fails to recover the biomechanics of a healthy finger. Nonetheless proximal interphalangeal (PIP) joint fusion was associated with limited impairment as index finger metacarpophalangeal (MCP) joint’s range of motion changed with only a few daily life activities [2]. However a single joint range of motion is not sufficient to appreciate the natural coordination that arises at multiple levels (muscles, joints, fingers) and allows an accurate and reliable precision pinch [3, 4].

The aim of this study was to investigate the effects of index finger PIP fusion on precision pinch kinematics. It was hypothesized that PIP joint fusion would led to 1) decreased maximal pinch aperture, 2) increased variability of joint angles and digit tips location at timing of contact, and 3) decreased joints coordination throughout the movement.

METHODS

Eleven healthy volunteers participated in this study. Fusion of the PIP joint was experimentally simulated with the adjunction of aluminum splints and adhesive tape following the protocol of [2]. Each subject performed cyclic pinching movements at a frequency of 1Hz. Four conditions were randomly tested: unrestricted (CONTROL), simulated PIP fusion at 30 (PIP30), 40 (PIP40), and 50 (PIP50) deg of flexion. Each condition consisted of 3 trials of 30 cycles.

Hand motion data was obtained by tracking attached reflective markers (4 mm in diameter) with a motion capture system (Vicon MX, Oxford, UK) (Fig. 1). The trapezium coordinate system was assessed according to [5] and joint angles computed with the Euler angles (rotation sequence of flexion, external rotation, and abduction).

Figure 1: PIP joint splinting and marker set-up.

For each pinch cycle, the pinching/closing phase was identified as starting at the maximal opening and ending at pulp contact. Maximal pinch aperture was calculated as the maximal distance between the digit tips marker. At pulp contact, joint angles and dispersion of tip markers were computed. Pearson’s coefficients of correlation between joint angles were calculated throughout the closing phases. Statistical significance of the effects of fusion condition was evaluated with one-way repeated measure analyses of variance and Tukey post-hoc tests (p <.5).

RESULTS AND DISCUSSION

Maximal aperture was 163.7, 153.5, 147.7 and 141.5 mm for CONTROL, PIP30, PIP40 and PIP50 respectively. Maximal aperture was significantly restricted with increasing PIP fusion angle by 6.2, 9.8 and 13.6 % for PIP30, PIP40 and PIP50 respectively (p <.001).

At the pulp contact, index finger joints compensated for the lost fused PIP joint. Index distal interphalangeal (DIP) joint angle increased with
increasing PIP fusion angle (10.6, 15.1, 16.2 and 17.7 deg for the CONTROL, PIP30, PIP40 and PIP50 conditions respectively). MCP joint angle significantly increased in the PIP30 condition (61.7 deg) in comparison to the CONTROL condition (53.2 deg) (p <.01). However, the MCP joint angles were not significantly different among the CONTROL, PIP40 and PIP50 conditions. The natural PIP angle for pinching recorded during the CONTROL condition was 44.1 deg which is close to PIP40 and PIP50. This may explain why the MCP joint angle did not change during those conditions and the PIP joint slightly adjusted. Thumb joint angles did not significantly change (p=.14).

PIP fusion did not lead to an increase in the variation (standard deviation) of individual joint angles at pulp contact. However the overall variability of the end effectors, as estimated with the dispersion of tip marker location, was affected. In particular, thumb tip location was significantly more variable (p<.01) in PIP50 than in the other the conditions (Fig 2). Thumb tip dispersion was 2.7, 2.6, 2.4 and 3.1 mm for the CONTROL, PIP30, PIP40 and PIP50 conditions respectively. No significant change was observed in index tip dispersion.

![Figure 2: 2D representation of joint angles variation and digit tips dispersion (mm) at timing of contact](image)

Pearson’s coefficients of correlation between joint angles revealed that both intra-finger (Index distal IP-MCP) and inter-finger (thumb IP- Index distal IP) coordination were affected. Dynamic coordination throughout the pinching phase decreased with PIP arthrodesis (Table 1).

<table>
<thead>
<tr>
<th>Thumb</th>
<th>Index</th>
<th>Both Digits</th>
</tr>
</thead>
<tbody>
<tr>
<td>IP-MP</td>
<td>MP-TMC</td>
<td>DIP-MCP</td>
</tr>
<tr>
<td>CONTROL</td>
<td>0.90</td>
<td>0.76</td>
</tr>
<tr>
<td>PIP30</td>
<td>0.87</td>
<td>0.68</td>
</tr>
<tr>
<td>PIP40</td>
<td>0.87</td>
<td>0.69</td>
</tr>
<tr>
<td>PIP50</td>
<td>0.90</td>
<td>0.74</td>
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</tbody>
</table>

*indicated a significant difference with CONTROL

**CONCLUSION**

This study aimed at analyzing the effects of PIP fusion on pinch kinematics. We first quantified that PIP fusion at 50 deg decreases pinch aperture by 13%, thus restricting the ability to grasp large objects. Furthermore we demonstrated that PIP fusion not only affects MCP joint motion [2] but also the coordination between digit joints. This eventually increases variability in thumb tip location and may lead to an overall impaired precision. Finally, the comparison between angles of fusion would suggest that increasing angle lead to more natural MCP joint angle but also to a more restricted aperture as well as a greater overall variability. As a limitation, this study simulated joint fusion without mimicking the underlying pathological mechanisms that lead to clinical fusion.

**REFERENCES**