BIOMECHANICS AND IMMUNOHISTOCHEMICAL STUDY OF MCL OF BIG TOE

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Introduction
Hallux valgus is a commonly occurring clinical disorder which has been the subject of numerous clinical studies. Attenuation of the medial collateral ligament (MCL) of the first metatarsophalangeal (MTP) joint has been implicated as a major factor related to development of hallux valgus. However, a specific structural degeneration or injury of MCL has not been identified. The purpose of this study is to examine the structure of collagen fibers and content proportion between type I and type III collagen, and correlate findings with mechanical properties of the ligament in normal and feet with hallux valgus deformity. The hypothesis is that stiffness and tensile modulus of the MCL is related to the proportion of type I and type III collagen, and collagen fiber structure.

Materials and Methods
Eleven cadaveric feet were studied; 7 normal and 4 with hallux valgus. Mechanical testing of MCL was performed to determine the load-deflection and stress-strain relationship. "Mechanical properties, structure of collagen fibers and content proportion between type I and type III collagen, and collagen fiber structure."

Results
In mechanical testing, both load-deformation and stress-strain curves had curvilinear patterns in which three regions were identified: laxity, toe, and linear regions. From these curves, laxity, stiffness in the toe region (Stiff) and in the linear region (Stiff) and tensile moduli in the toe region (E) and in the linear region (E) were obtained (Table 1). Laxity of MCL in hallux valgus feet (8.7±2.2 [mm]) was significantly larger than that of normal (4.3±2.6 [mm]). Stiff (60.9±21.3 [N/mm]) and E (13.7±2.4 [MPa]) in hallux valgus feet were significantly less than normal (Stiff, 92.7±16.3 [N/mm]; E, 22.7±4.3 [MPa]). However, Stiff and E were not significantly different between in hallux valgus feet (Stiff, 286.7±167.5 [N/mm]; E, 57.7±32.5 [MPa]) and normal (Stiff, 246.5±68.6 [N/mm]; E, 56.7±9.1 [MPa]). The MCL in hallux valgus feet demonstrated a more wavy configuration of collagen fibers than normal MCL (Fig. 1 (a) and 1 (b)). Immunohistochemical staining, there was a trend towards stronger staining of collagen type III in the hallux valgus MCL compared with that of collagen type I (Fig. 2 (a) and 2 (b)). On the contrary, no appreciable differences were identified in staining characteristics in collagen type I and III in normal MCL.

Discussion
The differences of stiffness in the toe region of the load-deformation curve is consistent with observation of wavy configuration of collagen fibers. Continuous and/or cyclic stress to the MCL in hallux valgus feet could cause microinjury of individual collagen fibers, which may alter the process of recovery, and affect continuity of collagen fibers. As a result, the configuration of collagen fibers becomes wavy, the MCL laxity increases and the stiffness in the toe region decreases. The persistent joint laxity may explain why bunion splints are ineffective in correcting hallux valgus deformity. In a previous immunohistochemical study, Liu et al. (1997) showed decrease of type I collagen but increase of type III in the healing process of tendon to bone insertion. In the present study, there was a trend in hallux valgus MCL towards stronger staining of collagen type III compared with that of collagen type I. Stiffness, and tensile modulus of MCL in linear region of load-deformation curve were same in HV feet and normals, suggesting limited effect on mechanical behavior due to alteration of MCL microstructure in HV feet. Data suggest that reconstruction of soft tissues about MTP joint in HV feet, including imbrication of MCL, will restore more normal mechanical properties to MCL.

Table 1: Laxity, tensile properties and sectional area of hallux valgus (HV) and normal MCL (mean±SD).

<table>
<thead>
<tr>
<th>Group</th>
<th>Laxity [mm]</th>
<th>Stiff [N/mm]</th>
<th>Stiff [N/mm]</th>
<th>E [MPa]</th>
<th>E [MPa]</th>
<th>Cross-sect area [mm²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV</td>
<td>8.7±2.2</td>
<td>60.9±21.3**</td>
<td>286.7±167.5</td>
<td>13.1±2.4</td>
<td>±32.5**</td>
<td>±13.8</td>
</tr>
<tr>
<td>Normal</td>
<td>4.3±2.6</td>
<td>92.2±16.3**</td>
<td>246.5±68.6</td>
<td>57.7±9.1</td>
<td>±32.5</td>
<td>±13.8</td>
</tr>
</tbody>
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*p=0.022; **p=0.030; †p=0.004

References

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