The anatomy of the joint as a risk factor for Lisfranc dislocation and fracture-dislocation

AN ANATOMICAL AND RADIOLOGICAL CASE CONTROL STUDY

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The anatomy of the mortise of the Lisfranc joint between the medial and lateral cuneiforms was studied in detail, with particular reference to features which may predispose to injury.

In 33 consecutive patients with Lisfranc injuries we measured, from conventional radiographs, the medial depth of the mortise (A), the lateral depth (B) and the length of the second metatarsal (C). MRI was used to confirm the diagnosis. We calculated the mean depth of the mortise (A+B)/2, and the variables of the lever arm as follows: C/A, C/B and C/mean depth. The data were compared with those obtained in 84 cadaver feet with no previous injury of the Lisfranc joint complex. Statistical analysis used Student's two-sample t-test at the 5% error level and forward stepwise logistic regression.

The mean medial depth of the mortise was found to be significantly less in patients with Lisfranc injuries than in the control group. Stepwise logistic regression identified only this depth as a significant risk factor for Lisfranc injuries. The odds of being in the injury group is 0.52 (approximately half) that of being a control if the medial depth of the mortise is increased by 1 mm, after adjusting for the other variables in the model.

Our findings show that the mortise in patients with injuries to the Lisfranc joint is shallower than in the control group and the shallower it is the greater is the risk of injury.

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metatarsal. Together with the intercuneiform interosseous ligament, it is one of the most important structures involved in the stability of the joint and disruption of either of these ligaments will cause disturbance of the stability between the medial and middle columns.

When evaluating injuries an anatomical approach to the tarsometatarsal joint helps to provide an accurate diagnosis. We have therefore attempted to determine if there are anatomical features of the joint which predispose to injury.

**Patients and Methods**

This study is in two parts, a radiological study of patients with injuries to the metatarsal joint and an anatomical examination of cadaver specimens.

**Injury group.** We studied retrospectively the radiographs of 33 consecutive patients with injuries to the tarsometatarsal joint. There were 23 men and 10 women with a mean age of 37.6 years (SD 16.4) (19 to 69). All had sustained a hyperflexion injury to the midfoot, mostly sports-related. The diagnosis of a Lisfranc fracture or fracture-dislocation was confirmed by CT and MRI in all cases. According to the classification system of Hardcastle et al., 29 patients had a B2-type injury (partial lateral), and two a B1-type (partial medial). The two remaining patients did not have a dislocation, but only a ligamentous lesion, so that classification was not possible. In 22 patients, lesions of the Lisfranc ligament were diagnosed by MRI.

Using standard anteroposterior (AP) and 45° oblique radiographs (Fig. 2) we measured the medial depth of the mortise (A) from the AP radiograph, its lateral depth (B)

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**Fig. 2a** – Diagram of a right foot. The distances A (the medial depth of the mortise), B (the lateral depth of the mortise) and C (the length of the second metatarsal) are illustrated. **Fig. 2b** – Conventional AP radiograph of a normal right foot. The distances A and C are illustrated by white lines. **Fig. 2c** – Conventional 45° oblique radiograph. The distance B is illustrated by white lines.

**Fig. 3a**

Anatomical specimen of the right foot of a male cadaver after dissection of the Lisfranc joint. The second metatarsal has been removed. Measurement of the distances A (a) and C (b) are shown.
from the 45° oblique radiograph, and the length of the second metatarsal (C) from the AP radiograph. All the radiographs were taken at a standardised distance of 114 cm. Using these measurements, we calculated the following coefficients: 1) \((A+B)/2\), the mean depth of the mortise; and 2) \(C/A\), \(C/B\) and \(C/\text{mean depth of mortise}\) which represent the ratios of the length of the lever arm to the depth of the mortise.

**Control group.** We obtained 84 cadaver specimens. The sex ratio was 1:1 and the mean age was approximately 65 years. The tarsometatarsal joint was dissected and no Lisfranc injuries were found. The same variables which were evaluated in the injury group were measured by direct visualisation (Fig. 3).

**Statistical analysis.** p values less than 0.05 were considered to be statistically significant. The mean differences between the injury and control groups and between males and females were tested using Student’s two-sample t-test assuming equal or unequal variance depending on Levene’s test for equality of variance after inspection of the data for symmetry of distribution. The test of dependency of anatomical variables on age was based on the Spearman correlation coefficient.

In order to determine which combinations of measurements of the Lisfranc joint are risk factors for injury stepwise forward logistic regression with the Wald criterion was performed. New risk factors were included if the p value was less than 0.05. The goodness-of-fit test of Hosmer and Lemeshow was applied to the final model. The regression coefficient is an estimate of the logarithm of the odds ratio for the injury for a change of unit in the corresponding variable, i.e., the ratio of the odds of being in the injury group to that of being a control for a unit increase in the corresponding explanatory variables, after adjusting for the other variables in the model.

**Results**

Table I gives the results of all measurements and calculations. All the variables were approximately normally distributed within each group. None of the measurements A, B or C was significantly related to gender (two-sample t-test) or age (Spearman correlation coefficient).

**Comparison of injury and control groups.** The mean values and the results of Student’s two-sample t-test are also given in Table I. The values of A and all coefficients

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Mean</th>
<th>Range</th>
<th>Difference of means</th>
<th>95% confidence interval (CI)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (mm)</td>
<td>Injury</td>
<td>8.95</td>
<td>4.0 to 15.0</td>
<td>-2.66</td>
<td>-3.5 to -1.8</td>
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<td>Control</td>
<td>11.61</td>
<td>6.0 to 16.0</td>
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<tr>
<td>B (mm)</td>
<td>Injury</td>
<td>4.74</td>
<td>2.0 to 8.5</td>
<td>-0.26</td>
<td>-1.0 to 0.5</td>
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<tr>
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<td>2.0 to 16.0</td>
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<tr>
<td>C (mm)</td>
<td>Injury</td>
<td>72.23</td>
<td>60.0 to 98.5</td>
<td>-1.17</td>
<td>-3.8 to 1.5</td>
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<td>73.39</td>
<td>62.0 to 85.0</td>
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<tr>
<td>(A+B)/2 (mm)</td>
<td>Injury</td>
<td>6.85</td>
<td>3.0 to 10.25</td>
<td>-1.46</td>
<td>-2.1 to 0.9</td>
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<td>Control</td>
<td>8.31</td>
<td>4.75 to 11.7</td>
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<td></td>
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<tr>
<td>C/A</td>
<td>Injury</td>
<td>8.63</td>
<td>5.4 to 14.3</td>
<td>2.13</td>
<td>1.4 to 2.9</td>
</tr>
<tr>
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<td>6.50</td>
<td>4.8 to 10.7</td>
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<tr>
<td>C/B</td>
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<td>9.3 to 39.5</td>
<td>1.57</td>
<td>-1.0 to 4.1</td>
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<td>Control</td>
<td>16.34</td>
<td>7.4 to 30.0</td>
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<tr>
<td>C/(A+B)/2</td>
<td>Injury</td>
<td>11.08</td>
<td>7.4 to 26.3</td>
<td>2.00</td>
<td>1.1 to 2.9</td>
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<td>9.08</td>
<td>6.76 to 15.4</td>
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</table>

<table>
<thead>
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<th>Odds ratio</th>
<th>CI</th>
<th>Wald criterion</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0.526 (0.40 to 0.69)</td>
<td>21.283</td>
<td>0.0001</td>
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<tr>
<td>B</td>
<td>0.917 (0.72 to 1.16)</td>
<td>0.528</td>
<td>0.47</td>
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<tr>
<td>C</td>
<td>0.972 (0.91 to 1.04)</td>
<td>0.743</td>
<td>0.39</td>
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<tr>
<td>(A+B)/2</td>
<td>0.502 (0.36 to 0.70)</td>
<td>16.107</td>
<td>0.00006</td>
</tr>
<tr>
<td>C/A</td>
<td>2.065 (1.45 to 2.95)</td>
<td>15.859</td>
<td>0.00007</td>
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<tr>
<td>C/B</td>
<td>1.040 (0.98 to 1.11)</td>
<td>1.494</td>
<td>0.23</td>
</tr>
<tr>
<td>2C/(A+B)</td>
<td>1.636 (1.26 to 2.13)</td>
<td>13.406</td>
<td>0.00025</td>
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</table>
containing A showed statistically significant differences between both groups.

**Logistic regression** (Table II). Measurement A (p < 0.0001) was selected in the first step of the stepwise logistic regression and all derived variables containing A were the only significant risk factors in this step. In the following step none of the remaining variables was selected and A remained the only variable in the final model. The regression coefficient revealed that the odds of being in the injury group is 0.52 (approximately half) that of being a control if the medial depth of the mortise is increased by 1 mm, after adjusting for the other variables in the model. The Hosmer and Lemeshow goodness-of-fit test gives p = 0.59, suggesting that the model is a reasonable fit.

**Discussion**

Dislocations and fracture-dislocations of the tarsometatarsal joint are usually the result of high-energy trauma. An indirect mechanism of injury has, however, also been implicated. This usually occurs in sports injuries or simple falls or sprains. Although rare, these injuries may cause considerable disability if they remain undiagnosed or are not properly treated.

The mechanism of indirect trauma to the midfoot consists of an axial force to a plantar flexed and inverted foot with additional secondary rotational forces. These cause disruption of the Lisfranc ligament which results in destabilisation of the entire joint complex.

Evaluation of the anatomical configuration of the mortise of the Lisfranc joint may assist in the diagnosis of tarsometatarsal fractures and fracture-dislocations. The radiological diagnosis of subtle Lisfranc injuries, such as isolated ligamentous lesions, may be difficult. Plain radiographs may be unreliable for the detection of these lesions.

CT and MRI, however, give an accurate anatomical delineation of the tarsometatarsal joint and the Lisfranc ligament. Clinical trials have shown the superiority of CT and MRI over conventional radiography, but a clear view of the mid-foot region by conventional radiography (dorsoplantar with 20° tilt, 45° oblique and true lateral) should be available before the use of CT and MRI.

The mortise of the Lisfranc joint between the medial and lateral cuneiform bones, which is considered to be the key for the stability of the joint, was significantly less deep in patients in the injury group compared with the control group. This implies that this group is at a greater risk of injury. In order to quantify this thesis, a logistic regression model was calculated. This model assumes that there is a linear and additive relationship between the log odds of having an injury and the explanatory variables.

All derived variables which involved the measurement A are significant risk factors for Lisfranc dislocation in the logistic regression analysis. A patient with a low A value (and thus a low mean depth, and high values of the derived variables C/A and C/mean depth) had a higher risk of injury to the Lisfranc joint complex. The lateral depth of the mortise, B, was not significantly different between the control and the injury groups. Neither the length of the lever arm at the site of injury, nor the length of the second metatarsal, C, was significantly different between the control and injury groups.

Within the injury group, there was no statistically significant relationship to gender or age for each of the measurements. There is no indication that a bias of the measurements is responsible for the differences in medial depth between those with an injury and the control group.

The data show that the medial aspect of the tarsometatarsal joint, between the medial cuneiform and the base of the second metatarsal, is the key to stability of this joint. This finding further suggests that the Lisfranc ligament is an important factor in the stability of the tarsometatarsal joint. The width of the ligament was not measured in either the injury or the control groups. It may be possible that the added depth of the medial aspect of the mortise may allow for a broader Lisfranc ligament, creating a stronger ligamentous structure and thereby reducing the risk of injury. This hypothesis will be evaluated by further anatomical studies.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

**References**


