Foot kinematics after unilateral calcaneal fracture: Results of a motion analysis study using a multi-segment foot model

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Summary
Patients with calcaneal fracture were examined postoperatively, to analyze foot function, using a 3D foot model. 16 persons were instrumented with 17 reflective markers and monitored by a motion capture system. A multi-segment foot model was used to evaluate the foot kinematics. The results show that the fracture leads to a functional deficiency of the ankle complex. This functional loss is not compensated for by an increase of mid- and forefoot motion, which instead displayed a reduced range of motion.

Introduction
The calcaneal fracture is commonly caused by high energy trauma such as falling from a height or by motor vehicle accidents. Reports on the long-term functional outcome have shown that complications like pain and disability are not uncommon. [1] The aim of this study is to evaluate the gait of patients after surgical treatment of calcaneal fracture using a new, more detailed foot model.

Methods
16 subjects (13 males, 3 females) who had suffered unilateral fractures of the calcaneus returned for clinical examination and gait analysis (follow up 59 months). The patients were instrumented with a set of 17 reflective markers and monitored by a 12-camera Vicon motion capture system. For the evaluation of foot kinematics a multi-segment foot model was used [2]. Differences in kinematics between uninjured and affected side were statistically evaluated using a t-test.

Results
The (total) ankle angle is the generally accepted parameter to describe motion between the lower leg and the foot [3], which is regarded as a rigid segment (A, Tab.1). A significant loss in the range of motion of the ankle was found in the pathologic/injured side with regard to both the total ankle angle (A, Tab.1) and the tibio-talar flexion (B, Tab.1), which only takes hindfoot motion into account [2]. Furthermore, range of motion with regard to subtalar rotation (D, Tab.1), movement in the medial arch (C, Tab.1), forefoot-ankle supination (E, Tab.1) and hallux flexion (F, Tab.1) were significantly reduced.

Conclusions
Fractures in the hindfoot involving the subtalar joint lead to a functional deficiency of the complete ankle complex. The diminished motion in the cardan joint complex, including the subtalar and tibiotalar joints, leads to a reduction of motion in the adjacent joints (A,B,C,D,E,F). In addition, this functional loss is not compensated for by an increase of mid- and forefoot motion; these parameters also appear to be reduced.

References
2. [Simon et al.]: Gait Posture 23 (2006) 411-424
<table>
<thead>
<tr>
<th>Description</th>
<th>Affected side</th>
<th>Uninjured</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) ROM Total Ankle Flexion</td>
<td>26.21 (3.86)</td>
<td>32.34 (4.29)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>(B) ROM Tibio-Talar Flexion</td>
<td>19.68 (2.70)</td>
<td>22.18 (3.19)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>(C) ROM Medial Arch</td>
<td>11.56 (3.15)</td>
<td>15.86 (3.97)</td>
<td>&lt;0.01</td>
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<tr>
<td>(D) ROM Subtalar Rotation</td>
<td>5.89 (1.63)</td>
<td>9.59 (2.15)</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>(E) ROM Forefoot-Ankle Supination</td>
<td>9.75 (3.02)</td>
<td>13.19 (3.70)</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>(F) ROM Hallux Flexion</td>
<td>39.90 (5.08)</td>
<td>45.91 (6.78)</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Mean (standard deviation)