A Statistical Analysis of Forces in Ankle Joint

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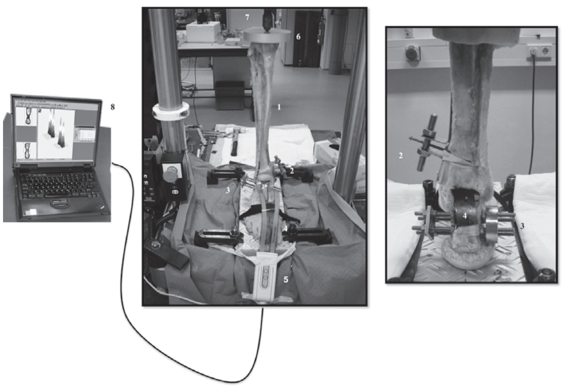
Malalignment of the hindfoot has been found to be one of the main risk factors for osteoarthritis (OA) of the ankle joint. It has been suggested that OA with frontal plane deformity can be addressed with distal realignment surgery. However, no biomechanical data on the effect of calcaneal osteotomy on supramalleolar deformities has been published.

Materials and Methods

The experimental set-up in Fig. 1 was configured to assess intraarticular pressure distribution in the ankle joint for various supramalleolar deformities, as well as for distal realignment surgery. 14 lower legs were placed in a loading apparatus with pressure sensors in the ankle joint, the deformities and the distal realignment were created and a force of 700 N was applied for 2 seconds recording the static pressure distribution in this time, and the results were analyzed carefully.
For the analysis several parameters were computed from the static pressure distribution, such as: centroid of forces, centroid 80% maximal pressure, axial force, and ratio. Three hypotheses were formulated: 1) Inframalleolar and supramalleolar deformities affect the ankle joint load distribution differently, 2) Calcaneal osteotomies affect the load distribution in both, mediolateral and anteroposterior, direction. 3) Calcaneal osteotomies in supramalleolar deformities do not normalize the ankle joint load distribution.



Experimental Set-up of the study. 1) cadaveric leg, stripped of soft tissue, 2) Wedges of different sizes were used to simulate various degrees of angular deformity in the supramalleolar area, 3) Calcaneal displacement plate to simulated distal realignment, 4) Tekscan 5033 pressure sensor for data recording, 5) Evolution USB Handle 6) Custom plate with a stem attached which inserted into the tibial marrow cavity for axial loading, 7) Instron actuator as the loading apparatus, and 8) K-Scan Software for data visualization.

The purpose of the simulation was to assess whether static pressure distribution of the neutral position measured experimentally could be reproduced using a FEM numerical model based on generic.

Results and Discussion

The purpose of this biomechanical study was to determine the effect of simulated supramalleolar deformities, and distal realignment surgery by a calcaneal osteotomy on the ankle joint load distribution.

Hypothesis 1): Although the overall alignment of the lower extremity is the same, e. g. same offset of the calcaneus with respect to weight bearing axis, the changes in the ankle joint are different in supramalleolar and inframalleolar deformities.

Hypothesis 2): We found that non-anatomical alignment correction of the hindfoot does not restore the ankle mechanics in the **invivo** model. Therefore isolated calcaneal osteotomies, which have been successfully used to treat hindfoot deformities such as cavovarus or planovalgus feet, may not be appropriate for the treatment of ankle arthritis.

Hypothesis 3): A significant finding is paradoxical pressure distribution after calcaneal osteotomy, inframalleolar valgus deformity lead to anteriomedial pressure overload. In inframalleolar varus deformity postero-lateral pressure overload is observed. Previous works were reviewed and two main differences between the experimental set-ups were established.

A simple comparison of the FEM model with the experimental data establishes accordance in the contact stress distribution, but a large difference in the maximal pressure value. The non-natural stress concentration may be caused by irregularities of the mesh where a sharp-pointed node could prevent the solver from performing an accurate contact analysis.

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