Architectural Reasons for the Femoral Neck Fracture Location

Wolfgang Gowin[1], Peter Saparin[1], Steffen Prohaska[2], Hans-Christian Hege[2], Stefan Beller[1], Dieter Felsenberg[1]

[1]Center of Muscle and Bone Research, Dept. of Radiology, University Hospital B. Franklin, Free University Berlin, Germany, [2]Konrad-Zuse-Institute Berlin (ZIB), Germany

Proximal femora harvested from human cadavers were examined within the framework of a space research project to develop 2D and 3D quantification parameters of the bone architecture. The results and findings of that project led to a sub-study aiming to find an anatomical substrate that can explain the high fracture frequency at the subcapital region of the femoral neck. A morphological reason for the frequency of this most common fracture location of all femoral fractures has not been described yet.

Ten proximal femora were scanned in high-resolution mode (0.2 x 0.2 mm) and in 1 mm slice thickness on a special configured XCT-2000 pQCT-scanner (Stratec, Germany). One specimen was excluded in the evaluation due to skeletal lesions of a leukaemia. 80 slices were acquired from each specimen. The data were visualized by the 3D data analysis platform Amira (Indeed – Visual Concepts, Germany). The BMD (bone mineral density) of each slice was calculated based on a calibration curve obtained from the scanner using an EFP (European Forearm Phantom). The software package provided by the pQCT-scanner contributed additional bone strength parameters. The architectural composition was quantified by 2D measures of complexity.

We found that the structural parameters such as the SCI (Structure Complexity Index) which quantifies the local complexity of the bone architecture, the TNI (Trabecular Net Index) measuring the trabecular richness, and the IGE (Index of Global Ensemble) quantifying the overall dynamics within the architecture are decreased in the transition area from the femoral head to the femoral neck. The lowest BMD of all slices, regardless of their average femoral neck BMD, was found in that same transitional region. The BSI (Bone Strength Index) based on the polar moment of resistance is decreased in this area as well.

The subcapital femoral neck fracture is with 86% of all femoral neck fractures (German statistics) overrepresented in that skeletal region. Fall mechanisms and biomechanical considerations alone cannot explain this high accumulation of fracture in the transitional zone between femoral head and neck. The fracture frequency increases exponentional in that region with increasing age, thus making the reduction in BMD a good reason for the loss of bone strength. However, dramatic changes in the structural composition of the trabecular bone in that area indicate that the architecture of the bone tissue cannot be neglected in the considerations for the reasons of the fracture. The changes in architectural composition are an important contributing factor for the increased material incompetence.

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