Introduction: Surgical treatment of proximal humeral fractures still remains a challenge. This is primarily due to the fact that sufficient implant-fixation in humeral head fractures is often not achieved due to substantial bone tissue loss with increasing age. Knowledge of the patterns of osteoporosis and its relationship to the bone mineral distribution and mechanical properties is therefore required for an optimization of implant anchorage. In addition, knowledge of the distribution of bone strength throughout age allows prognostic statements about proximal humerus fractures and their clinical treatment. The hypothesis for the present study was that bone mineral density and mechanical strength changes in the various regions of the proximal humerus as a function of age and gender. The goal was to determine the age and gender related distribution of mechanical strength and BMD which may help to evaluate the optimal implant-bone anchorage implant design studies in future.

Methods: 70 fresh humeral bones from human cadavers without focal bone disease or osteoarthritis were obtained. Thus, 24 paired and 22 non-paired humeral specimens were considered for the study (46 individuals; 23 males, 23 females). The median age of all specimens was 70.5 years (min.: 34 years, max.: 95 years). The humeral head was divided into 4 equal horizontal sections (B1-B4; Fig. 1). In order to determine the Cortical Index (CI), radiographic analysis was performed. BMD measurements were achieved with a DXA-scanner. In addition QCT was performed. The ROIs (1 cm²) were defined in the 4 section levels. Mean CT-numbers were calculated for each specimens with indentation tests using a cylindrical indentator (8.5 mm resolution mode with 0.4 mm slice thickness was applied resulting in a voxel ROI. The same sections as for QCT were obtained by pQCT, although a high defined in the 4 section levels. Mean CT-numbers were calculated for each specimens in BMD were not seen in specimens of age 69 years or younger (p>0.05). In significant correlation in the male group (p>0.01). Gender-related differences found (p<0.01) with statistically significant differences between specimens of the group of female specimens of age 70 years or older, BMD values were found to be significantly lower compared to their male counterparts (p<0.05). All modalities correlated well CI/pQCT: rho=0.0491, DXA/pQCT: rho=0.839; QCT/pQCT: rho=0.797, p<0.01). Regardless of the specimen’s age, the highest BMD was found at the proximal aspect and the medial and dorsal regions of the proximal humerus. A statistically significant high correlation was found between the BMD-distribution and the mechanical strength in indentation testing (rho=0.93, p<0.01), see figure 2.

Discussion: For the first time this study reports the age and gender-related reduction in mechanical strength of trabecular bone in the humeral head and relates this finding to clinical measures such as BMD. These findings may have an impact on the understanding and treatment of humeral fractures in three ways: 1. The fracture risk is increased in female patients over the age of 70 years due to reduced BMD. 2. The reduced bone quality in certain regions of the proximal humerus may be the cause of the multiple fragment fractures which are frequently seen in the clinic. 3. Due to the reduction of bone mineral density and mechanical strength in certain parts of the humeral head, fixation of the implants becomes a challenge, especially, if knowledge on the average local distribution of bone mass is limited. Previous radiological analyses of the proximal humerus showed a decrease and a change of bone mass with increasing age and in descending sections from the cranial to the caudal sections. Especially those implants used for the intramedullary stabilization of proximal humeral fractures are placed in the center of the humeral head where BMD was found to be decreased in QCT (central ROI). However, a high BMD was found in the dorsal aspect of the humeral head, which is rarely used for implant fixation. This finding of considerable amounts of trabecular bone in the dorsal aspect is supported by clinical experience. QCT and pQCT are the only non-invasive modalities capable of differentiating trabecular and cortical density at a skeletal site. Results on QCT of the proximal humerus have been presented only in two studies so far, both with a small number of cases [1, 2]. Similar to these, we found a correlation between the cancellous bone mass and its mechanical strength. The findings of our study showed a maximum of BMD and mechanical strength in the cranial section medial and dorsal, regardless of age and gender. The minima of BMD and mechanical strength were found in the central area and in the area of the lesser and greater tuberosity. Even though BMD and mechanical strength decreases in these areas over age, the distribution pattern of BMD and mechanical strength within these areas remains approximately the same.

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References:

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