Abstract: Cyclic deformation and fatigue behaviour in cancellous bone

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The fatigue behaviour of materials is of particular interest for the failure prediction of materials and structures exposed to cyclic loading. For trabecular bone structures only a few sets of lifetime data have been reported in the literature and structural measures are commonly not considered. The influence of load contributions which are not aligned with the main physiological axis remains unclear. Furthermore site and species dependent relationships are not well described. In this study seven different groups of trabecular bone, defined in terms of orientation, species and site were exposed to cyclic compression. In total, 108 fatigue tests were analysed with respect to lifetimes, deformation behaviour and damage accumulation. Furthermore, damage mechanisms were derived from novel measurement methods for the optical strain analysis on the apparent and tissue level. The lifetimes were found to decrease drastically when off-axis loads were applied. Additionally, species and site strongly affect fatigue lifetimes. While the characteristics of cyclic deformation were found to be similar for all groups, large deviations were observed for the fatigue lifetimes. Bovine specimens did reveal higher lifetimes compared to human samples and lifetimes decreased with increasing deviation of the specimens' axis from the physiological bone axis. Already small deviations cause a large reduction, whereas deviations above 45° result in a similar fatigue behaviour. Strains at failure were found to be dependent on specimen orientation (with respect to the physiological bone axis). The whole cyclic deformation process as well as damage evolution until defined failure could be shown to be a function of normalised stress and group. The corresponding functional relationships were derived. Damage acceleration was found to be constant for all specimens and different damage mechanisms are acting for on-axis and off-axis groups. Likewise, load thresholds were found, at which damage mechanisms change from low-cycle to high-cycle fatigue. Age appeared to have a large influence on the initial modulus of the specimens. Deformation analysis on the apparent and the trabecular level could be linked to macroscopic damage and microdamage was found to contribute to residual strain accumulation. Concluding, the axis of loading appears to contribute dominantly to fatigue and cyclic deformation, which may be even more pronounced in cases of increased anisotropy (Osteoporosis). Therefore, local morphological information has to be included in risk of fracture predictions in order to achieve a higher reliability.