Influence of Age and Mechanical Stability on Bone Defect Healing: Age reverses Mechanical Effects

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Introduction: Both systemic biological factors and mechanical stability affect the outcome and course of bone defect healing [1,2]. It has been shown that age produces a delayed course of bone healing [3]. A high instability can lead to rupturing of callus tissue, but also too rigid fixation can delay healing process [1,3]. Separate influences of age and mechanical stability are well known but in clinical reality both factors act simultaneously. This animal study is the first which tries to find a crosslink between the both factors for possibly finding therapeutic consequences.

Materials and Methods: 36 female Sprague-Dawley rats were divided into 4 groups of 9 animals. Group 1 (YS) and 3 (YR) were 12 weeks old and group 2 (OS) and 4 (OR) were 12 month old. In all rats the left femur was osteotomized, distacted to an osteotomy gap of 1.5mm and finally externally fixated. In groups 1 and 2 a semi-rigid setup (15mm offset, stability: torsional 6.22 Nmm°, axial 10.39 N/mm) and in groups 3 and 4 a rigid setup (7.5mm offset, stability: torsional 8.13 Nmm°, axial 25.21 N/mm) of the fixator was chosen. Every 2 weeks after surgery X-rays were done. For statistical analysis a t-test was used (2 perpendicular views: A – all 4 cortices bridged, B – one to 3 cortices bridged, C – no bridging) [4]. For quantitative analysis the bone diameter and the maximum diameter of the callus was measured (Photoshop® CS, San Jose, USA) and the calculated ratio of cross sectional area (CSA, callus/bone) was compared. 6 weeks after surgery the animals were sacrificed and both femurs of the rats were harvested. Number of pseudarthrosis was recorded. The bones were torsional loaded until failure (Zwick 1445, Ulm, Germany) as described previously [4]. Groups were compared by torsional stiffness (TS) and the maximum torque at failure (MTF), reported as percentual values of the contralateral bone. Statistical analysis of the biomechanical and quantitative X-ray-data was performed 2-tailed using ANOVA and posthoc Bonferroni test. X-ray and pseudarthrosis score were tested with the chi-square-test. Interobservervariability was tested by kappa-statistics. Alpha was 0.05 in all tests. Statistical analysis was performed using SPSS 14.01 (SPSS Inc., Chicago, USA).

Results: 6 weeks after surgery TS of the group 3 (YR: 175.78±34.79%) was significant higher than that of the other groups (YS: 77.56±24.24%, P=0.001; OR: 25.11±8.35%, P<0.001; OS: 38.23±21.19%, P<0.001). Additionally, group 1 (YS) showed a significant higher TS compared to the group 2 (YS/OS P=0.006) and group 4 (YS/OR P=0.046). Between the groups of old rats (OS, OR) no significant difference in pseudarthrosis could be found. At 2-week follow-up group 3 (YR: 147.66±41.57%) showed a significant higher TS compared to the group 2 (YS/OS P=0.006) but not than group 4 (OR: 194.15±36.27%). The young rigid (YR) fixated rats showed a higher MTF compared to group 1 (YS: 54.38±40.63%) and 2 (OS: 50.44±13.45%, P=0.046) and 3 (YR: 98.79±51.64%, P=0.004). The young rigid (YR) fixated rats showed a higher MTF compared to group 1 (YS P=0.012) and group 2 (OS P=0.001) (Fig.2). No significant differences in pseudarthrosis between the groups could be found. At 2-week follow-up group 3 (YR) showed a higher MTF compared to group 1 (YS P=0.006) and at 6 week follow-up groups 1 (YS) and 3 (YR) (P=0.032) showed a significant higher radiographic score. After 2 weeks relative CSA of the callus was significant higher in group 1 (YS: 191.32±51.47%) compared to the groups 2 (OS: 137.12±16.24%, P=0.025) and 4 (OR: 122.88±29.44%) but not group to 3 (YR: 142.88±16.46%, P=0.055). At 4-week follow-up CSA was significant different between group 1 (YS: 224.70±35.83%) and 3 (YR: 154.56±17.85%, P=0.002). Between the other groups no significant differences could be found (OS: 182.14±37.58%; OR: 193.54±17.07%). At 6 weeks group 3 (YR: 147.66±18.22%) showed a significant lower CSA than groups 1 (YS: 250.54±63.06%, P= 0.002) and 2 (OS: 223.89±26.89%, P=0.03) but not than group 4 (OR: 194.15±40.63%).

Discussion: This study demonstrated that bone defect healing outcome is dependent to age and mechanical environment whereas the same mechanical environment can lead to inconsistent healing success in different age groups. The effect of age seems to invert the effect of mechanical properties of the callus, which could not get correlated to the CSA. Maybe differences in tissue composition and calcification at the time-point of testing can explain the measured biomechanical effects [5]. Age seems to play a major role whether mechanical stability leads to healing success or not. Animal studies in bones without fracture or osteotomy could show that young compared to old bones show higher bone growth under the same mechanical stress and that old bones need a higher level of stress for an equal level of remodelling [6, 7]. Therefore, in future age-adapted fixation devices using different rigidities may lead to lower incidences of a pseudarthrosis.

References: