The Effect of Inverse Dynamization on Bone Healing

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Disclosures:

Introduction: It is well known the healing of fractures is influenced by the mechanical environment and studies have shown that not all phases of bone healing are equally sensitive to mechanical stimuli. However, the most beneficial regimen of mechanical stimulation in different phases of healing is not currently known. We hypothesize that it will be beneficial to flexibly stabilize the fracture during the earlier proliferative stage of healing, in order to promote larger callus formation, and then to stiffen the fixation later to promote callus consolidation and mineralization. Thus, the aim of this study is to determine the effect of a change from flexible to stiff fixation (termed inverse dynamization, ID) on fracture healing.

Methods: A custom-made external fixator was implanted on the right femur of rats using four threaded stainless steel pins [1, 2]. An osteotomy gap of 1 mm was created in femurs between the two inner pins of the fixator. An offset of 6 mm, from the fixator bar to bone surface, was used for a stiff configuration, and 12 mm was used to produce a flexible configuration. Inverse dynamization was performed at 3, 7 and 21 days post surgery by decreasing the distance of the fixator to the bone. Two control groups with constant stiff and flexible fixation were also tested. After five weeks the rats were euthanized and bone healing was evaluated with biomechanical testing and qualitative and quantitative image analysis. The flexural rigidity of the healed femurs was determined from a three-point bending test normalized to the contralateral femur. The size and mineral content of the fracture callus was analysed from microcomputed tomography (µCT) images.

Results: From the biomechanical testing it was found that the flexural rigidity (Figure 1a) in the stiff control group was significantly higher compared to the flexible control group. Dynamization after 3d, 7d and 21d led to a significantly higher flexural rigidity at 5 weeks than in the flexible control group. There was no statistical difference between the stiff group and the inverse dynamization groups, although the highest flexural rigidity values were obtained in the 7d ID group. Results from biomechanical testing were supported by the qualitative µCT (Fig.1b). The most advanced healing stages were identified in the stiff control and 7 day ID group which were both characterized by a more uniform and advanced cortical bone repair and reestablishment of the marrow canal. Furthermore, in these two groups the callus size and volume was similar indicating comparable states of healing (data not shown). The 3 day and 21 days groups were less advanced and followed lastly by the flexible group.

Discussion: The time to healing could be improved if the fixation was flexible initially followed by stiffening of the fixation around the 7 days. Performing this process earlier or later in healing period produced less beneficial effects when compared to the stiff control group. However by performing inverse dynamization late in the healing period (21 day ID group) the healing outcome can be significantly improved compared to flexible conditions. This indicates that stiffening of a fracture that is in an overly flexible condition for an extended period of time can lead to an accelerated healing outcome. Overall this study suggests that inverse dynamization has the potential to enhance the outcome of fracture healing. However, further investigation is required into the most optimal timing of ID and to understand the mechanobiological mechanisms.

Significance: Currently, 5-10% of fractures fail to heal in a timely manner due to poor mechanical conditions. The results of this study are significant for the design of fracture fixation devices and rehabilitation programs.

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enhances fracture healing in a rat femoral osteotomy model. *Journal of orthopaedic trauma.* 25(3): 169-

**Figure 1:** a) Flexural rigidity of the operated femur (mean value ± standard deviation, p<0.05) after 35 days of healing, normalized to contralateral femur; b) representative cross-sectional μCT images through the center of the fracture gap.