Reverse Dynamization Accelerated Bone Healing in a Large Animal Osteotomy Model

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What was the question?
Studies have shown that manipulation of the local mechanical environment around a fracture site influences fracture healing. Understanding the nature of these mechanical cues, and the biological responses is very important as this ultimately determines the quality, the type of tissue formed, and the rate and success of the healing process. The mechanical environment is determined by the stiffness of fracture fixation and weight bearing; if fixation is either too flexible or too rigid, then the healing might fail. Based on this knowledge, some authors have suggested that the delayed introduction of controlled motion, dynamization, changing from a rigid to a more flexible fixation as healing progresses, may lead to faster maturation of bone. However, the benefits of this process have been very modest, and has not greatly influenced clinical practice. In contrast, superior healing has been previously reported using a counter intuitive process called Reverse Dynamization in a small animal model, where the fracture is initially fixed with a more flexible, followed by a rigid fixation. The hypothesis is that a fracture that's initially stabilized less rigidly would allow micromotion and encourage cartilaginous callus formation, and once substantial callus has formed, the stabilization is converted to a rigid configuration to allow vascularization and accelerated remodeling. Therefore, the aim of this study was to investigate if bone healing can be accelerated using Reverse Dynamization in a 2 mm goat osteotomy model.

How did you answer the question?
Fifteen immature, neutered male Spanish cross goats underwent an identical surgical procedure after IACUC approval. Each goat had a circular external fixator applied to the right hind limb using the same construct: reference wire and two half pins on the proximal ring and two wires and a half pin on the distal ring block. A transverse 2 mm osteotomy was created halfway between the proximal and middle rings using a sagittal saw. The goats were then divided into three groups: Static group (S, n=6; four threaded rods connecting the proximal and middle rings to stabilize the fracture), Dynamized group (D, n=6; four threaded rods containing the 2 mm axial dynamizers to stabilize the fracture), Reverse Dynamization group (RD, n=3; started with the 2 mm axial dynamizers and were converted to threaded rods at three weeks after surgery). The goats were allowed to begin weight bearing immediately after surgery. Each animal had weekly pin care and radiographs of the fracture site. At the end of week 8 the goats were euthanized, and both limbs of each goat were evaluated using MicroCT and mechanical testing. Statistical analysis was performed between the experimental groups after each sample was normalized to the corresponding contralateral bone values. For comparisons between the groups, an unpaired T–test was performed, with differences considered statistically significant at $p < 0.05$.

What are the results?
Weekly radiographs showed earlier and bigger callus formation in the Dynamized groups (D and RD). In agreement with weekly radiographs, MicroCT results showed that the callus size was

bigger and achieved near significance between Static vs. Dynamized groups (D $p=0.08$ vs RD $p=0.06$), but it was not different between both dynamization groups. There was more bone formed in both dynamization groups (D and RD) compared to the Static group, but significance was only reached

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between the Static and Dynamized groups ($p=0.04$). Bone volume fraction was also significantly different between Static and Dynamized ($p=0.05$), but was not different between Static and Reverse Dynamized groups. Bone mineral density was higher in the Reverse Dynamized group compared to Static and Dynamized group which reached nearly significant difference ($p=0.06$). Moreover, the tibial defects that healed under conditions of Reverse Dynamization were considerably stronger in torsion than the defects stabilized with Static and Dynamized fixation regimens ($p=0.02$ and $p=0.01$ respectively). Furthermore, tibias in the Dynamized groups (D and RD) were also significantly different from the intact bone (for both $p=0.001$).

What are your conclusions?

This preliminary data confirm the influence of modulating the mechanical environment on the healing of osteotomies in the goat model. The best results were achieved using Reverse Dynamization as was demonstrated by torsional testing and microCT. The bones that healed under the Reverse Dynamization regimen were significantly stronger and had higher bone mineral density, suggesting accelerated remodeling process. This data agreed with previous small animal studies demonstrating that the axial stiffness of the fixator can be modulated to maximise the regenerative capacity of bone healing. Although promising, the sample numbers per group were relatively small, therefore, those findings will have to be confirmed in a larger study.