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BIOPHYSICAL STIMULATION ON BONE REPAIR & REMODELING

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INTRODUCTION: Bone defect and material weakness may lead to fracture even under minor trauma. There are drugs, biologic factors, and biophysical stimuli, which may provide effective fracture repair enhancement. However, fixation stability, extent of surgery, and bone reduction are prerequisites for successful bone healing. Delayed union, mal-union, or non-union will affect patient's quality of life and health care cost. This paper describes the potential augmentation effect of biophysical stimulation on bone fracture repair and an implementation system using a hierarchical approach and knowledge-based execution concept.

PEMF ON OSTEOTOMY HEALING: Canine mid tibia osteotomy was used to study the effect of PEMF on bone union (Fig. 1). Significant increase in new bone formation and mechanical strength was achieved using different dose of stimulation. The contra-lateral intact limb exposed to the PEMF also increased bone strength significantly. The initial biologic effect was cell mediated but the bone strength enhancement was primarily due to increased vascular activity that enhances callus maturation and prevents bone resorption.

CORTICAL DEFECT REPAIR: Cortical defect was used to study the effect of loading on bone repair and remodeling (Fig. 2). Weight bearing was a significant permissive factor on the initial defect repair. Using micro corrosion casting technique, increased vascular formation was found to associate with local tissue strain energy density. At 16 weeks, bone structural strength recovered but not its morphology. This is an ideal creeping substitution model to investigate various bone repair enhancement factors and their dose effect.

KNOWLEDGE-BASED STIMULATION: A computer-aided and knowledge-based stimulation implementation system was conceptualized (Fig. 3). Signal transducer capable of delivering focalized stimulation to assure efficacy and safety will be developed. An ultrasound imaging device is used to monitor bone strength non-invasively in order to adjust stimulation signal and dose to optimize tissue response. An Expert System utilizing basic science and clinical knowledge to customize stimulation protocol with intermediate adjustment will be incorporated. This technology should be regulated to restrict its use and reimbursement only to licensed physicians and bioengineers.

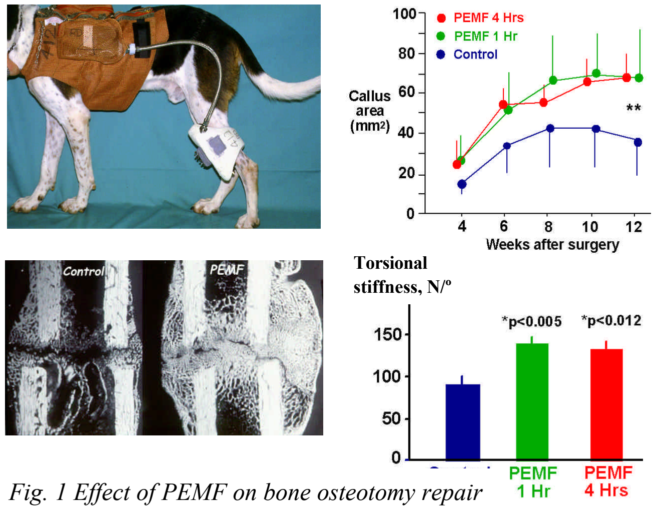

Fig. 1 Effect of PEMF on bone osteotomy repair

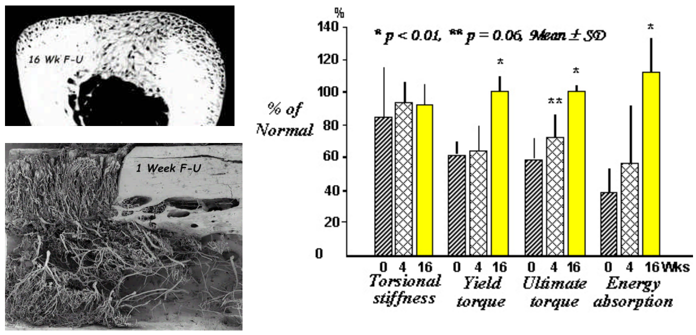

Fig. 2 Cortical defect repair

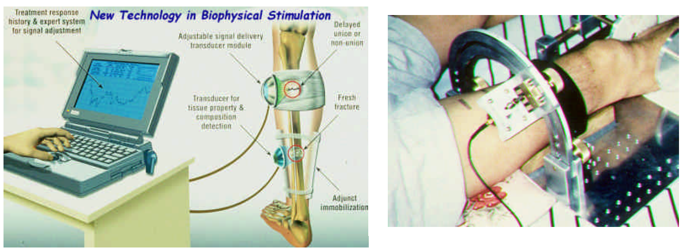

Fig. 3 Computer-aided biophysical stimulation

DISCUSSION & CONCLUSIONS: The basic science of biophysical stimulation is well-established but the technology for its application lags far behind. The lack of treatment control and effective signal delivery was only one of many limiting factors. If a reliable system can be developed with efficacy assurance, biophysical stimulation could become a tool for bone "Tissue Engineering" non-invasively. Bone remodeling, however, remains a biomechanical event that cannot be substituted by biophysical stimulation.

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