The effects of Low-Intensity Pulsed Ultrasound Stimulation on Maturation of Regenerate Bone —— A Rabbit Limb Lengthening Model

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Introduction: Bone lengthening by distraction osteogenesis is a well-described method of addressing bony deficits due either to congenital or acquired (e.g. traumatic) conditions. While plastic deformation and refracture have been associated with premature removal of the fixator device, a relatively high rate of complications also occurs early in the treatment course. Low intensity pulsed ultrasound (LIPU) has been shown to have a positive effect on the enhancement of fresh fracture and delayed bone union[1], but its effect on the consolidation phase of distraction osteogenesis and bone transportation has not been substantiated. We hypothesized that the LIPU signal characteristics and application used for bone fracture healing enhancement would carry the same positive effect on bone regenerate maturation when applied in the callus consolidation phase after bone lengthening.

Materials and Methods: Sixty skeletally mature female New Zealand White rabbits randomly assigned to LIPU treatment group and the control group in a blinded fashion to test the effects of LIPU stimulation on bone regenerate maturation during the consolidation phase of limb lengthening. All animals after mid-diaphyseal tibial osteotomy were immobilized in an Orthofix Mini lengthener. Gradual distraction of 0.5 millimeters every twelve hours for a ten-day period was performed following a seven-day latency period. A 4-week course of LIPU stimulation (Smith & Nephew Inc., Memphis, TN, USA) was applied over the distraction site for twenty minutes daily starting immediately after the completion of distraction. Animals were followed until sacrifice at 4, 8, 12 weeks after the completion of the bone lengthening protocol. Radiographic, bone mineral density (BMD) measured by Dual Energy X-ray Absorptiometry (DEXA) and torsional testing to failure were performed on the bone specimens. After breaking the blinded stimulation code, the treatment and control group results were compared.

Results: The results of biomechanical testing showed LIPU enhanced the torsional stiffness, ultimate torque, energy absorption at failure (Table 1). And radiographic measurement showed higher relative gray scale of bone callus in LIPU group presented when compared with that in the control group at 8 and 12 weeks (P<0.05) (Table 2). BMD in LIPUS group was significantly higher than that in control group at 8 and 12 weeks (Table 2).

Discussion: Bone lengthening by distraction osteogenesis requires a considerable investment in both time as well as clinical resources. A modality effective in improving the rate and quality of regenerate bone maturation may significantly improve the clinical treatment outcome. This study demonstrated that LIPU as a biophysical stimulation enhanced the formation and maturation of regenerate bone in rabbit tibia lengthening model.


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Table 1 Torsional properties of healing tibial diaphysis ( %, normalized to the opposite non-operative tibia) (Data presented as Mean ± SD)

Table 2 Total callus area, relative gray scale and relative BMD of newly formed bone (normalized to the opposite non-operative tibia) at the distraction site at week 8 and 12 (Data presented as Mean ± SD)

Fig. 1 Time Schedule of Animal Study Protocol