Effects of Low-intensity Pulsed Ultrasound Stimulation on Porous Hydroxyapatite Blocks for Posterolateral Fusion of Lumbar Spine in Rabbits: An Experimental Study

INTRODUCTION:
Lumbar posterolateral fusion (LPLF) is a common surgical procedure for treating several spinal diseases. The extensive utilization of autologous bone and allograft was limited for various causes. The synthetic porous hydroxyapatite (HA) as substitute for bone graft has been used for decades in clinical practice, although it lacks the osteoinductive property. Studies have shown that low-intensity pulsed ultrasound stimulation (LIPUS) may be used safely together with HA ceramics to increase bone in-growth into the pores of ceramic material and to accelerate the process of bone fracture repair, the healing of delay union or nonunion. However, the effects of a combined use of LIPUS with HA graft on spinal fusion have not been reported. We investigated the hypothesis that LIPUS would accelerate osteointegration between the HA graft and the host bone through a combined osteoconductive and osteoinductive actions, consequently the rates and the time of spine fusion could be improved.

METHODS:
1. Materials: The HA ceramics (Hunan Gong Chuang Biofunctional Materials Ltd. Co, Hengyang, P.R. China) was a rectangular block of 5 mm in width and height and 30 mm in length. The interconnected porous ranges from 200 μm to 500 μm.
2. The LPLF model in rabbits: Twenty adult rabbits underwent LPLF with HA or autografts of ilium were randomly designed two groups: group A treated with 20-minute LIPUS daily and the control group B. The lumbar spine of each rabbit was harvested en bloc at 5 week after operation.
3. Fusion evaluation: The fusion was measured by manual palpation test, gross observation, radiography, histomorphology, and scanning electron microscope. (Note: The gray scale value of the plain callus image represented bone mineral density (BMD). The difference value (D-value) of gray scale between before and after treatment represented the BMD change.).
4. Statistical analysis: The data were presented as Mean ± SD. The treatment effects for all continuous response variables were evaluated using a two-way ANOVA followed by a factorial analysis procedure. The statistical significance level was set at p < 0.05.

RESULTS:
1. Fusion rate evaluated by palpation (Fig. 1A) and observation (Fig. 1B).

2. The effects of LIPUS and grafts on D-value of gray scale of callus mass were presented.

3. The effects of LIPUS and grafts on new bone formation were presented.

DISCUSSION:
The results of this study confirmed our initial hypothesis and indicated that LIPUS may have played a positive, or osteoinductive role in improving HA integration with the spine and thus enhancing fusion outcome. We found that there were more osteoblast-like and chondroblast-like cells at the interface between HA and host bone in group A when compared with group B, while there were no difference on cells between HA and autogenous iliac bone graft. In addition, the BMD of fusion mass was significantly increased in group A. These results showed that LIPUS accelerated endochondral ossification, bone callus remodeling, and bone in-growth into porous HA block. By the results of palpation and observation, it can draw that LIPUS promoted LPLF, and the fusion effect indicated that LIPUS may have played a positive, or osteoinductive role in improving HA integration with the spine and thus enhancing fusion outcome.

CONCLUSION:
LIPUS can accelerate endochondral ossification, bone callus remodeling, and bone in-growth into porous HA blocks. The use of LIPUS in combination with a porous HA block bone graft substitutes may further improve the treatment results in LPLF.

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REFERENCE:

Fig. 3 Photomicrograph of sagittal sections of junction of HA and host bone showed that the osteoblast, chondroblast, and the new bone area in group A were significantly greater when compared with that in group B (P<0.05). H&E staining. 40X.

Fig. 4. The bar diagram demonstrated the difference of the number of osteoblast and chondroblasts at the interface of HA and host bone between group A and B. The results of factor analysis: the main effect of A factor (LIPUS) = 13 (P = 0.000 < 0.01). The main effect of B factor (graft) = 4.4 (P = 0.761 > 0.05). These mean that LIPUS can accelerate cell differentiation and proliferation but B (graft) cannot.

Fig. 5 The SEM images showed more osteoblast-like and chondroblast-like cells ingrowth into the pore of HA block, and attached and coupled on the surface of porous HA block in group A compared with group B.