INTRODUCTION

Bio-electrical and physical stimulation on lengthening callus have been clinically applied for its usefulness, such as a less-invasive method, acceleration effect to osteoblast differentiation, and shortening of the external fixation period, and we also reported that alternating current (AC) stimulation (30 μA electrical stimulation for 24 hours) accelerated the maturation of regenerate callus 3). However, the validity of an electrical intensity and stimulation time are unclear, and high-intensity stimulation may produce tissue damage. This study was aimed to examine the effect of the low-intensity (10 μA) and short time stimulation (20 minutes) to the regenerate callus radiographically, electrophysiologically, and histologically.

METHODS

A mid-diaphyseal osteotomy at the right tibia was performed in twenty-four Japanese white rabbits and an external fixator (Orthofix M100, Orthofix Inc., Italy) was applied. After 7 days latency, the tibias were lengthened at a rate of 1mm daily, for 10 days. The 24 rabbits were equally divided into three groups, control group (C-group), 10 μA and 30 μA electrical stimulation group (ES10 and ES30 group, respectively), and each divided into 2 and 4 weeks after completion of distraction (Fig.1). ES-groups were stimulated for 20 minutes daily, using AC stimulator (MES, Co., Ltd., Tokyo). Radiographic examinations and measurement of impedance values (Z values) between fixation pins using impedance meter (MES, Co., Ltd., Tokyo), in order to analyze the electrical conductivity, were performed once a week following distraction. In weeks 2, 4 (n = 4, for each group) after completion of distraction, bone mineral density (BMD) on the 10mm distraction area were measured with a dual energy X-ray absorptiometry (Aloka, Co., Ltd., Tokyo), and the lengthened part of the tibia was stained with hematoxylin and eosin (HE).

Statistical analysis was performed by using Mann-Whitney’s U test. P values less than 5% were regarded as statistically significant (p<0.05).

RESULTS

Radiographic findings

After completion of distraction, the mineralization bands around the proximal and distal ends of the osteotomized tibia progressed toward the center and fused at 2 weeks. Tubular formation by new cortical bone was observed at 4 weeks, and thickening of cortical bone was observed in ES-groups.

Impedance

Although Z values in C-group gradually increased with time after distraction, in ES-groups, they demonstrated a slight decreasing trend through 4 weeks (Fig.2).

Bone mineral density

BMD decreased significantly from 2 to 4 weeks in both C- and ES-groups (p<0.05), but in ES-group, the rate of decrease was lower than that of C-group. There was a significant difference at 4 weeks between C- and ES10-groups (p<0.05) (Fig.3).

Histology

At 2 weeks, enchondral ossification was observed in ES-groups as compared with C-group, and corticalization was progressed at 4 weeks. The volume of callus was not different between C- and ES-groups.

DISCUSSION

Eyres et al. reported that BMD of a lengthened callus reached to the highest level when the lengthened bone was filled with a callus, and that it decreased in accordance with the distribution of corticalization and mineralization. They also reported that it reached to the constant low level after tubular structure was completed 4). In this research, although BMD of C- and ES-groups decreased significantly from 2 to 4 weeks as the report of Eyres, since BMD of ES10-group in 4 weeks was higher than that of C-group, 10 μA electrical stimulation for 20 minutes maintained BMD of the regenerate callus. Furthermore, from the examination of the electrical impedance between fixation pins, although the volume of callus was not different, Z values in ES-groups did not increase consistently, so that the maturation of the distraction site was considered to progress as compared with C-group 3). Histological findings demonstrated that the enchondral ossification was accelerated in ES-group, although callus size was not significantly different between groups. These results also supported that AC stimulation accelerated the maturation of regenerate callus, that not the proliferation but the differentiation of corticalization and medullarization was promoted in the callus. As for AC stimuli, 30 μA electrical stimulation for 24 hours daily have been well accepted to date, but the above results showed and confirmed that such less-invasive method of 10 μA electrical stimulation for 20 minutes also accelerated the maturation of the lengthened callus, and that it could shorten the time course of callus lengthening.

REFERENCES