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Utilization of Atomic Force Microscopy to Examine Surface Ultrastructural Changes in Bone Tissue Following Pulsed Electromagnetic Field Therapy for Osteoporosis in Rats

Objective

To investigate the changes in the surface ultrastructure of the femoral neck in an experimental rat model of osteoporosis and to evaluate the feasibility of using atomic force microscopy (AFM) for these observations.

Methods

Sixty female SD rats (3 months old, weighing 200±20 g) were randomly divided into four groups: control group (Sham group), ovariectomy group (OVX group), alendronate treatment group (ALN group), and pulsed electromagnetic field treatment group (PEMFs group), with 15 rats in each group. Bilateral ovariectomy was performed on the OVX and PEMFs groups. On the 30th day after modeling, different interventions were applied to each group. The ALN group received alendronate by gavage,while the PEMFs group underwent pulsed electromagnetic field treatment. The Sham and OVX groups were maintained on a normal diet post-surgery without additional treatment. After 30 days of treatment, the rats were sacrificed under anesthesia, and femoral head slices were collected for analysis. The surface ultrastructure of the femoral neck was then examined using atomic force microscopy (AFM).

Results

In the Sham group, AFM scanning revealed the presence of bone lacunae, bone canaliculi, and calcium-phosphorus crystal deposition on the surface of the bone tissue, with a measured surface roughness of 2.59±0.645 μm. In the OVX group, alterations in the size of bone lacunae and a disordered arrangement of calcium-phosphorus crystals were observed. The surface roughness of bone tissue in the OVX group was significantly higher compared to the control group ($P<0.01$), confirming the successful establishment of the osteoporosis model. The surface roughness in the ALN group was significantly lower than that in the OVX group ($P<0.05$). Similarly, the surface roughness in the PEMFs group was markedly reduced compared to the OVX group, with a statistically significant difference ($P<0.05$). However, no significant difference in surface roughness was observed between the PEMFs group and the ALN group ($P>0.05$).

Conclusion

Atomic force microscopy effectively demonstrated alterations in the surface ultrastructure of bone tissue following pulsed electromagnetic field treatment for osteoporosis in a rat model. The therapeutic efficacy of this intervention was found to be comparable to that of alendronate, providing a solid theoretical foundation for the application of pulsed electromagnetic fields in osteoporosis treatment.

Key words: Atomic Force Microscopy, Pulsed Electromagnetic Field, Osteoporosis, Ultrastructure

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图1

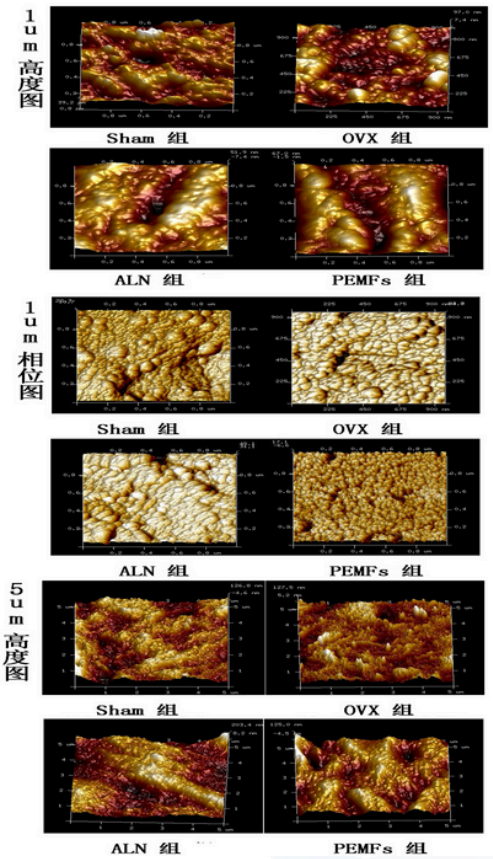
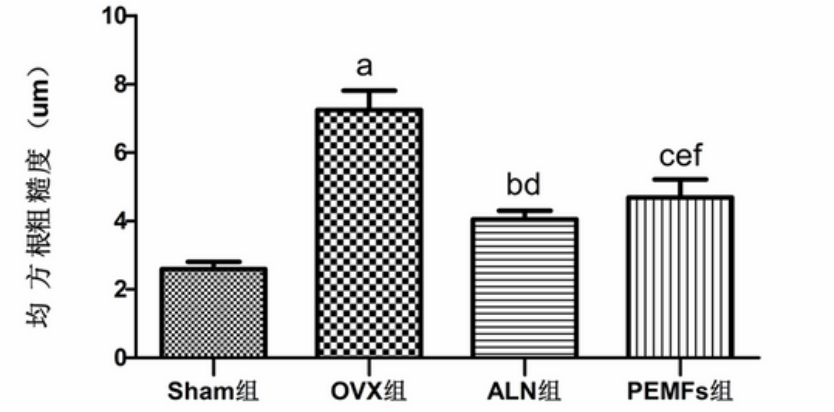


图2



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