The healing process of intracorporeally and in situ devitalized distal femur by microwave in a dog model and the biomechanics of the dog and human cortical bone treated by microwave in vitro

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Abstract

Background: Limb-salvage surgery has been well recognized as a standard treatment and alternative to amputation for patients with malignant bone tumors. Various limb-sparing techniques have been developed including tumor prosthesis, allograft, autograft and graft-prosthesis composite. However, each of these methods has short- and long-term disadvantages such as nonunion, mechanical failures and poor limb function. The technique of intracorporeal devitalization of tumor-bearing bone segment in situ by microwave-induced hyperthermia after separating it from surrounding normal tissues with a safe margin is a promising limb-salvage method, which may avoid some shortcomings encountered by the above-mentioned conventional techniques.

Purposes: The purpose of this study is to assess the healing process and revitalization potential of the devitalized bone segment by this method in a dog model. In addition, the immediate effect of microwave on the biomechanical properties of bone tissue was also explored in an in vitro experiment.

Methods: We applied the microwave-induced hyperthermia to devitalize the distal femurs of dogs in situ. Using a monopole microwave antenna, we could produce a necrotic bone of nearly 20 mm in length in distal femur. Radiography, bone scintigraphy, microangiography, histology and functional evaluation were performed at 2 weeks and 1, 2, 3, 6, 9 and 12 months postoperatively to assess the healing process. In a biomechanical study, two kinds of specimens, the dog and human cortical bone, were used. For the dog cortical bone, the compression and three-point bending test were conducted respectively immediately after extracorporeally devitalized by microwave. For the human cortical bone devitalized by microwave in vitro, the static tensile and compressive tests were performed. The tensile and compressive strength, the fracture work and the stretching rate were measured.

Results: Our in vivo study showed that intracorporeally and in situ devitalized bone segment by microwave had great revitalization potential. For the in vitro study with dog cortical bone, the results revealed that the initial mechanical strength of the extracorporeally devitalized bone specimen may not be affected by microwave. However, as for the human cortical bone during in vitro test, the compressive strength was greater than the normal bone. The tensile strength did not change greatly, while the tensile stretching rate decreases greatly. Furthermore, both of the compressive and tensile fracture works of bone treated by microwave reduced greatly.

Conclusions: Our in vivo study showed that intracorporeally and in situ devitalized bone segment by microwave had a great revitalization potential. The in vitro biomechanical results indicated that the hyperthermia induced by microwave might worsen the flexible capacity of cortical bone and thus make the bone fragile. Therefore, to protect the weakened bone and decrease the fracture rate during healing, rigid internal fixation and prolonged protected weight-bearing may be necessary. In general, our results suggest that the intracorporeal microwave devitalization of tumor-bearing bone segment in situ may be a promising limb-salvage method.