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Influence of 1800 MHz GSM-like Electromagnetic Radiation Exposure on Fracture Healing

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Background and Aims. In this study, we aimed to investigate whether 1800 MHz frequency electromagnetic radiation (EMR) has an effect on bone healing.

Methods. A total of 30 Wistar albino rats were divided into two equal groups. Fractures were created in the right tibias of all rats; next, intramedullary fixations with K-wire were performed. A control group (Group I) was kept under the same experimental conditions except without EMR exposure. Rats in Group II were exposed to an 1800 MHz frequency EMR for 30 min a day for 5 days a week. Next, radiological, mechanical, and histological examinations were performed to evaluate tibial fracture healing.

Results. Radiological, histological and mechanical scores were not significantly different between groups (respectively, $p = 0.114$, $p = 0.184$ and $p = 0.083$), and all of these scores were lower than those of the controls.

Conclusions. EMR at 1800 MHz frequency emitted from cellular phones has no effect on bone fracture healing.

Key Words: Fracture healing, Electromagnetic radiation, Mobile phone, 1800 MHz, GSM.

Introduction

Bone fracture healing is a crucial process with respect to its important socioeconomic and overall quality of life outcomes. Various local and systemic factors can affect fracture healing in positive or negative ways. Fracture healing and bone tissue formation are complex metabolic processes associated with various local and systemic regulators and involve reciprocal interaction of the cellular structures (1−5). The bone repair process begins with hematoma formation, which occurs after skeletal injury and bone fracture. This process continues with the inflammatory phase followed by the formation of soft and hard callus tissues, which ultimately leads to the remodeling phase (6,7). However, fracture healing may not necessarily result in such a favorable outcome, and there are always some disruptions. Currently, there are some ongoing studies focused on obtaining more insight into the pathophysiological background of bone healing and the factors that influence the process. It has also been revealed that bone formation and fracture healing involve electrical activity (8). Some findings related to the possible effects of electrical stimulation or pulse electromagnetic radiation (EMR) on fracture healing have been reported (9,10). There are many local, systemic or environmental factors that may affect bone formation and fracture healing in positive and negative ways (1−7). Bone tissue can potentially absorb the environmental EMR, and mobile phones can be one of the environmental sources of EMR (11).

Several negative outcomes of EMR related to human health, particularly involving the endocrine and nervous

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systems, have been reported; these outcomes are a result of the interaction of some peripheral EMR resources such as cellular phones and base stations with living biological structures (12–18). Cellular phone-based EMR frequencies belong to the high frequency band radiofrequency (RF) in the electromagnetic spectrum (12,19,20). High frequency EMR emitted from cellular phones and base stations may have some negative effects on biological tissues, and bone formation/fracture healing can be affected by these peripheral sources (7,20–22). In a study by Yildiz et al. (21) in which EMR at 1 ± 04 mW/cm^2 power was applied for 30 min a day for 5 days a week over a period of 4 weeks, it was reported that the mean femoral and vertebral bone mineral density (BMD) values of the rats exposed to 900 and 1800 MHz RF EMR were lower than those of the controls; however, this difference was not statistically significant. In another experimental study (11), it was reported that short- or long-term exposure to EMR at a 900 MHz frequency had no significant effect on the bone tissues of rats. Atay et al. (23) showed a decrease in mean BMD of the pelvic ring bone tissues of individuals who stored their cellular phones on or near their belts. Çiçek et al. (24) reported a decrease in fracturing power, bending resistance and total fracture energy in bone tissues of rats exposed to RF EMR at 1800 MHz. Aydogan et al. (25) reported that there was no prominent difference between the controls and the study group based on histopathological scores following 1800 mHz RF EMR exposure in an experimental rat patellar joint cartilage damage model. Furthermore, the effect of high frequency 1800 MHz EMR on fracture healing is still unknown, and there is no published study on this issue in the literature to date. In this study, we investigated whether high frequency EMR at 1800 MHz emitted from cellular phones affects bone fracture healing.

Materials and Methods

Animal Model

A total of 30 adult Wistar albino male rats aged between 4 and 6 months and weighing 256 ± 20 g were included in this study. The animals were obtained from the Animal Research Laboratory of the Medical Faculty of Suleyman Demirel University (SDU). Before the initiation of the experimental part of the study, written approval consent was granted from the local Ethics Committee of SDU School of Medicine. Male rats were preferred for this study because they have no short periodic or cyclic hormonal changes, which occur in females (26), and they have been commonly used in animal models of experimental orthopedic surgery. Rats were equally and randomly divided into two groups as follows: Group 1 (controls, $n = 15$) and Group 2 (exposed to 1800 MHz EMR, $n = 15$). The rats were kept under ideal humidity and circadian rhythm conditions (temperature: 22 ± 2°C, 12 h light-dark cycle, humidity: 30–70%). They had access to standard pellets (rat diet) ad libitum. The animals were not restricted in terms of activity and/or loading-stress during the experiment. Only Group 2 animals were exposed to EMR, whereas Group 1 controls were not; both groups were housed in the same room.

EMR Application Setting

An RF generator (Set Elec. Co. 900/1800 Lab.Test Transmitter, Model 8050 GX, Istanbul/Turkey), which can produce outputs between 0 and 4 W at 1800 MHz, was used to produce the signals at cellular phone working frequency. RF EMR was applied to the rats using half-wave dipole antennas at 1800 MHz. At the SDU Electronic and Communication Engineering Research Laboratory, the power intensity and the EMR near the dipole antenna were measured while the RF generator was operating at the 2 W level; the whole rat body SAR value was theoretically calculated as 0.008 W/kg. Rats near the dipole antenna were exposed to EMR at a 1.04 mW/cm^2 power intensity. SAR values and theoretical analysis calculations were based on the method described by Gajsek et al. (27,28).

Surgical Method

All rats were food deprived for 12 h prior to the operation. Prophylactic cephazolin sodium (Sefazol® [15 mg/kg]; Mustafa Nevzat İlaç Sanayii A.Ş. İstanbul, Turkey) was administered i.m. 2 h before the surgical intervention. Ketamine HCl (Ketalar® [10 mg/kg]; Pfizer İlaçları Ltd. Şti, İstanbul, Turkey) and xylazine HCl (Alfazyne® [0.25 mg/kg]; Ege Vet Hayvan. Tic. Ltd. Şti, İzmir, Turkey) were i.p. injected for general anesthesia. Manually induced fractures and intramedullary fixation methods were applied as previously described (22). We preferred the intramedullary fixation approach because it is a standard method (29). Moreover, it is very easy to remove intramedullary rods prior to histological and/or biomechanical procedures. Right tibial bones were transversely broken with finger pressure based on the three-points principle. After this procedure, the right posterior regions of the legs were cleaned with antiseptic solution, covered with sterile green dressings and prepared for the operation. A 1.5-cm long incision was made on the anterior of the right knee. Using a scope, the fracture line was ligated and stabilized using the intramedullary fixation method with 0.5-mm-thick K-wires, which were inserted from the proximal tibia and passed through the intramedullary route. The incision site was closed with running 4–0 prolene. The fractures were classified according to their appearance based on a previously described method with modifications (22). The good condition was defined as one fracture line located between the proximal 1/3 and the distal 2/3 of the bone, and the bad condition was defined as partial, multisegmental fractures or fractures with articular involvement. Fractures that were