Proliferation Effects of 42-kHz Radio Frequency Energy on Human Foreskin Fibroblasts

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Abstract

Radio frequency (RF), which can penetrate the dermis to induce cell responses, has been frequently used in the field of skin regeneration. This study examines the potential of using RF treatment for skin wound healing. Human fibroblasts were exposed to a 42-kHz RF at various intensities for 30 min. The cell cycle progression, cell viability, and c-fos and c-jun gene expressions were evaluated using flow cytometry, an MTT assay, and reverse-transcription polymerase chain reaction after individual exposures. The results show that the DNA synthesis, cell viability, and gene expressions were upregulated by low-level RF, especially at 350 and 450 A/m^2 of electromagnetic field exposures. Therefore, RF may play a predominant role in inducing cell proliferation through cell cycle progression and c-fos and c-jun mRNA activation. Non-thermal RF may be the major cause of generating the cell response.

Keywords: Radio frequency, Fibroblasts, Bio-effects

1. Introduction

Wound healing is a complex and dynamic process that involves interactions among soluble mediators, blood cells, extracellular matrices (ECMs), and parenchymal cells [1]. Inflammation, tissue formation, and tissue remodeling, which overlap, are essential phases during wound healing. To regenerate wound tissue, dermal fibroblasts are activated by cytokines and released from macrophages to support skin healing [1]. After the bleeding and inflammatory phases, fibroblasts migrate to the wound margins, proliferate, and secrete ECMs, such as proteoglycans and glycosaminoglycans, to provide a scaffold for directing supportive cells to the injury site and to synthesize more ECMs. However, ischemia, infections, fibroblast inactivity, and wound protease imbalances hinder wound healing, as reported in studies on diabetic, burned, and chronic pressure ulcer patients [2,3]. Therefore, developing an effective method for redundancy reduction has become critical.

Physical therapy modalities are widely applied to wound healing enhancement, such as electrical, ultrasonic, and low-level laser stimulations [4]. Electrotherapy can stimulate fibroblast growth [5], decrease ulcer size [6], and expedite healing time [7]. Although exogenous electric stimulation assists in the healing process, the current density and voltage distributions are unstable during in vivo applications [8]. Ultrasound (US), which is a type of mechanical stimulation, has longitudinal waves that are used for diagnosis and therapy. Research has suggested that US might facilitate chronic wound regeneration in vivo [9], regulate fibroblastic proliferation [10], and induce ECM deposition [11]. Its noninvasiveness and safety make US one of the most acceptable approaches in clinical applications. However, a medium is necessary for energy propagation, such as water or a coupling gel, and thus there is a risk of infection at the medium contact site. Low-level laser treatment is another promising method for facilitating wound healing [12]. However, the machinery is expensive and the outcomes are controversial. Although these treatments can benefit cell responses, some obstacles must be overcome. Therefore, an effective modality for accelerating wound healing is necessary.

Radio frequency (RF) is one of the most innovative treatments for chronic wound healing and skin regeneration. It has been shown to reduce skin flaccidity, wrinkles, and cutaneous aging [13]. In addition, RF has demonstrated the ability to upregulate human dermal cell proliferation [14,15] and activate expressions of genes and enzymes [16-19]. Moreover, RF generates a non-ionizing electromagnetic field, considered a safe modality for mammalian, and has been used in both medicine and communication depending on the frequency spectrum. For example, the spectrum between 3 and 30 GHz is within the microwave band; the range of 30 to 300 MHz is used for FM radio broadcasts and land mobile stations (emergency and military). Furthermore, RF treatment is non-contact and noninvasive [20-22]. RF may play a

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