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The Effects of Microcurrents on Inflammatory Reaction Induced by Ultraviolet Irradiation

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Abstract. [Purpose] This study examined the effects of microcurrents on inflammatory reactions induced by ultraviolet irradiation. [Subjects and Methods] We recruited 22 subjects and two inflammatory reaction regions were induced on the lumbar region of each subject with ultraviolet irradiation. Microcurrents were applied to one region at a frequency of 5 pps, an intensity of 50 μA, and alternation of no microcurrents were applied to the other region polarity. The irradiated regions were analyzed by at 1 sec intervals; the digital image analysis and the quantitative sensory test. [Results] Changes in chromatic red and luminance there were statistically significant showed over time and between regions. The comparison of wound contraction in the two regions there was a statistically significant difference. Analysis of changes in pain threshold showed no statistically significant difference. [Conclusion] This study found that microcurrents increased wound contraction and reduced the inflammatory reaction activities such as erythema and pigmentation. Thus, we consider that microcurrents help to accelerate the inflammatory reaction induced by ultraviolet irradiation, enhance recovery and foster an anti-inflammatory reaction.
Key words: Microcurrent, Inflammatory reaction, Ultraviolet

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INTRODUCTION

Ultraviolet radiation (UVR) (mainly UV-B: 280–315 nm) is a powerful agent that can alter the normal state of life by inducing a variety of mutagenic and cytotoxic DNA lesions such as cyclobutane-pyrimidine dimers (CPDs), 6–4 photoproducts (6–4PPs), and their Dewar valence isomers as well as DNA strand breaks by interfering with genome integrity[1)]. Ultraviolet is divided into UVA, UVB and UVC depending on its influence on is an organism. In particular UVA and UVB to the human body[2,3)], and UVA radiation poor inducing DNA damage, because it is not absorbed by human DNA[1)]. Defined doses of UVB irradiation lead to visible erythema as a local sign of inflammation, which is caused by the formation of prostaglandins and the release of inflammatory mediators[1)].

Recently, therapy using electrical stimulation as well as medication has been widely used, and in particular, microcurrents, which have excellent efficacy in wound healing at currents below 1000 μA, which don't cause muscular contraction, and has been widely used for acute phase treatment because it gives patients an easy feeling and has electrical stability and no side effects[4)].

Microcurrents have been found to increase the number of organelles responsible for cellular activities in tissue, and to increase concentrations of ATP, the cellular source of energy[5)]. Becker[6)] reported that lesions were reported successfully reparied by electrical stimulation, and Carey and Lepley[7)] reported that electrical stimulation increases microcirculation and fosters the transfer of macrophages and leukocytes affecting wound healing. Also, Harrington et al.[8)] and Brown et al.[9)] reported that electrical stimulation increases the growth of epithelial cells generated in the process of wound healing, and Al-Waili et al.[10)] stated that electrical stimulation accelerated wound healing. Szuminsky et al.[11)] reported that electrical stimulation sterilized bacteria and inhibited the growth of cells which affected wound healing.

Most previous research has focused on the effects of wound healing, but recent studies[10)] of microcurrents have centered on the therapeutic effects of microcurrents applied to muscular fatigue and pain relief[12)], wound healing[10)], and the effects of microcurrents on inflammation artificially induced by injecting drugs. However, experiments examine inflammatory reactions caused by photochemical action have rarely been reported. Thus, this study aimed to examine the effects of microcurrent on inflammatory reactions caused by repeated UVB irradiation.

SUBJECTS AND METHODS

The subjects of this study were 22 female volunteers with good health who were in their twenties. The criteria of selection were those who had no anti-allergen drug use, no

long-term exposure of the lumbar region to sunshine for the recent 6 months, no scar or wound on the lumbar region, no sensory disturbance, no cutaneous disorder, or duration of inflammatory reaction for over 24 hours. Before conducting the experiment, the general process of the experiment was explained to the subjects and their consent to participation in the experiment was obtained.

The mean age of the subjects was 21.5 ± 0.9 years old, their mean height was 161.2 ± 4.3 cm and their mean weight was 54.7 ± 4.9 kg.

An ultraviolet, HOHENSONNE 3030 (ORIGINAL HANAU, Germany) was used and its wavelength was 311.60 nm. The subjects exposed their lumbar region to the ultraviolet radiation in a prone position on a bed and a cloth with two holes 2 cm in diameter was fixed over the lumbar region using tape at vertical intervals of 5 cm in order to induce two inflammatory reactions at a distance of 2.5 cm away from the L1 spinous process the distance between the ultraviolet lamp and the lumbar region was 30 cm.

The degree of inflammatory reaction was set on the basis of the 3rd erythema dose which was five times the minimum erythema dose according to the clinical judgment criterion of erythema and ultraviolet irradiation was applied 5 times for 10 minutes with 1 minute break in order to avoid tissue damage such as edema.

For the microcurrent, Endomed (Enraf-Nonious B.V. Co., Netherlands) was used. Before applying the microcurrent, the subjects maintained a prone position on the bed and their skin was washed with alcohol to reduce electrical skin response. The parameters of the microcurrent were; a frequency of 5 pps, a stimulus intensity of 50 μA, and a rectangular monophasic waveform with the polarity alternating at 1 sec intervals. One of two electrodes was attached to the region where the microcurrent was applied and the other was attached to the thoracic region at a distance of 5 cm away and upward from the L1 spinous process so as not to affect the sham region. The microcurrent was applied once a day for 20 min for 6 days. The same adhesive electrode was attached to the sham region but no microcurrent was deliverd.

A digital camera (KENOX U-CA4, Samsung Co., Korea) was used for image capture. The subjects kept a prone position within a styrofoam box for digital image capture and their lumbar region was exposed to show the microcurrent and sham regions. The distance from the lumbar region to the camera lens was 30 cm and that from both ends of the styrofoam box to the whole section was 55 cm. The edge of the styrofoam box was blocked by the cloth in order to prevent light reflection and shadow formation and digital imaging was conducted three times with lighting at both ends of the styrofoam box.

Image analysis was conducted using the image pro plus 4.5 program (Media Cybermetics, USA). After analyzing the chromatic red value, luminance value and area (pixel) value, the mean value of the three images was used.

The RGB mean value of the inflammatory region for chromatic red and luminance was calculated and the chromatic red value and luminance values were calculated using the following expression.

$$\text{Chromatic red (r)} = \frac{R}{R+G+B} \times 100$$

$$\text{Luminance (L)} = \frac{R+G+B}{3}$$

Wound contraction (%) was calculated from the pixel area of the inflammatory region and then by the following expression.

$$\text{Wound contraction (\%)} = \frac{\text{Wound area day (0)} - \text{Wound area day (n)}}{\text{Wound area day (n)}}$$

For the quantitative sensory test, Von Frey (Patterson medical Co., USA) was used. Thin and thick filaments were used on the subjects in a prone position on the bed and the mechanical pain threshold in the region where inflammatory reaction was induced was measured. After obtaining the filament of pain threshold which a subject felt, three repeated measurements were conducted using filaments in an irregular order to avoid adaptation of tactile a sense.

Statistical analysis was performed using SPSS 12.0 program for Windows. After establishing the measured items were normally distributed with the Kolmogorov-Smirnov test, repeated measures ANOVA was conducted to examine differences in the changes of the two regions for chromatic red, luminance, and pain threshold by time and the paired t-test was used to compare the differences in mean values of wound contraction. The level of significance was chosen as α=0.05.

RESULTS

Changes in chromatic red between the two regions and period showed statistically significant differences ($F=3.770$, $p<0.05$). The sham region showed a slow decrease from an average of 43.2 ± 1.4 one day after UV radiation exposure to an average of 41.9 ± 1.1 six days after UV radiation exposure, and the microcurrent region showed a larger decrease from an average of 43.01 ± 1.03 one day after UV radiation exposure to an average of 40.7 ± 1.2 six days after UV radiation exposure (Table 1). Changes in luminance between the two regions and period showed statistically significant differences ($F=2.082$, $p<0.05$). The sham region showed a slow decrease from an average of 130.0 ± 3.3 one day after UV radiation exposure to an average of 130.4 ± 1.3 six days after UV radiation exposure, and the microcurrent region showed a lager decrease from an average of 130.9 ± 3.2 one day after UV radiation exposure to an average of 133.8 ± 3.0 six days after UV radiation exposure (Table 2). In the comparison of wound contraction, there was a significant difference between the two regions ($t=2.20$, $p<0.05$). After 6 days, the wound had decreased in area by about 21% more in the microcurrent region than in the sham region (Table 3). Changes in pain threshold showed no significant main effect and no interaction effects were found. The sham region little change from before induction of inflammatory reaction with an average of 4.4 ± 0.6 one day after application and average 4.7 ± 0.8 six days after UV radiation exposure, and the microcurrent region showed

Table 1. Comparison of chromatic red between the microcurrent region and the sham region (unit: %)

Region	Pre	2nd day	4th day	6th day
Microcurrent	44.0 ± 1.0	42.6 ± 0.7	42.0 ± 1.1	40. 7 ± 1.2
Sham	44.0 ± 1.0	43.2 ± 1.1	42.8 ± 1.3	41.9 ± 1.1

Mean ± SD. There was a statistically significant interaction between the two regions and period ($F=3.770$, $p<0.05$).

Table 2. Comparison of luminance between the microcurrent region and the sham region (unit: pixel value)

Region	Pre	2nd day	4th day	6th day
Microcurrent	129.8 ± 8.5	131.7 ± 3.2	132.7 ± 3.5	133.8 ± 3.0
Sham	129.8 ± 8.5	130.3 ± 2.4	130.0 ± 5.2	130.4 ± 1.3

Mean ± SD. There was a statistically significant interaction between the two regions and period ($F=2.082$, $p<0.05$).

Table 3. Comparison of wound contraction between the microcurrent region and the sham region (unit: pixel value)

Region	Pre (wound area)	6th day (wound area)	Contraction (%)
Microcurrent	1507.2 ± 273.2	673.4 ± 122.8	55.3 ± 55.1
Sham	1357.4 ± 297.9	887.9 ± 145.8	34.6 ± 21.0

Mean ± SD. There was a statistically significant difference between the two regions ($t=2.20$, $p<0.05$).

Table 4. Comparison of pain threshold between the microcurrent region and the sham region (unit: g)

Region	Pre	2nd day	4th day	6th day
Microcurrent	4.4 ± 0.7	4.3 ± 0.6	4.5 ± 0.6	4.7 ± 0.8
Sham	4.4 ± 0.7	4.4 ± 0.6	4.6 ± 0.7	4.7 ± 0.8

Mean ± SD. No significant main effect and no interaction effects were found.

little difference form the sham region with an average of 4.3 ± 0.6 one day after UV radiation exposure and an average of 4.7 ± 0.8 six days after UV radiation exposure (Table 4).

DISCUSSION

Previous research has shown that microcurrents influence tissue changes in the process of wound healing[9,10,13]. This study conducted digital image analyses and quantitative sensory tests to examine the effects of microcurrents on temporal tissue reactions such as the inflammatory reaction.

Changes in chromatic red were digitally analyzed. The chromatic red value of the exposed area rapidly increased after ultraviolet irradiation, and the microcurrent and sham regions showed rapid increased in chromatic red after one day. However, the microcurrent region showed much greater decreases in chromatic red than the sham region from the second to the sixth day.

It widely known that a decrease in chromatic red indicated an erythema reaction[14], and a study comparing the therapy effects of microcurrent therapy and laser therapy in the process of wound healing reported that microcurrents were effective at reducing the inflammatory reaction[15]. These results suggest that the release of prostaglandins and inflammatory mediators is induced by ultraviolet irradiation causing an inflammatory reaction such as the erythema reaction and that[7], microcurrents reduce prostaglandins and the release of inflammatory mediators thereby helping to reduce the inflammatory reaction.

Changes in luminance were digitally analyzed. The luminance value rapidly decreased after ultraviolet irradiation and the microcurrent region showed greater more increases in luminance than the sham region from the 1st day to the 6th day. Luminance indicates homogeneity of tissue healing in the wound region and indicates the brightness of the region[14], Choi et al.[16], in their study, measured skin color with a colorimeter and argued that brightness reflects the pigmentation caused by melanin synthesis. Therefore, we consider that increase in luminance in the microcurrent region was due to the recovery of the dark skin tone induced by temporal pigmentation after ultraviolet irradiation to the state before, because

microcurrents reduced the activation of melanin synthesis. We also found that microcurrents increased wound contraction. Poltawski and Watson[13] reported that endogenous fields are intrinsic to a number of metabolic processes, including development, adaptation and repair. In addition, it is known that electrical stimulation fosters division and transfer of fibroblasts and keratinocytes, increases DNA and protein synthesis ability leading to wound healing[17]. A study which examined wound contraction depending on polarity, using the same alternation of polarity as in this study, also reported that electrical stimulation was effective at increasing the wound contraction[18]. Thus, we consider that the greater increase of contractions in the microcurrent region than in the sham region was caused by microcurrents fostering activities of cells such as fibroblasts and keratinocytes.

In the analysis of the pain threshold, we found that microcurrents didn't affect the pain threshold. A difference between preceding studies and this study is that the inflammatory reaction was limited below the 3rd erythema minimize tissue damage like edema and there were no changes in pain threshold even after induction of the inflammatory reaction.

This study has limitations in that the subjects were of specific age and gender, and the microcurrent of was also limited to specific parameters, so it is difficult to generalize the results. Therefore, studies of the effects of microcurrents on inflammatory reactions induced by ultraviolet irradiation with wider subjects ranges of age and gender, and microcurrent parameters will be required.

In conclusion, we consider that microcurrents help to reduce the activities of the inflammatory reaction, such as erythema reaction and pigmentation, as assessed by decreasing chromatic red and increasing luminance and wound contraction. The results of the present study furnish basic data for the further study of the effects of microcurrents on inflammatory reactions induced by photochemical actions such as ultraviolet irradiation.

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