In vitro study of penetration of magnetic particles into the human skin

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ABSTRACT

We present experimental study of penetration of magnetic particles into the human skin *in vitro*. The administration of the particles through the skin into the body leads to localization and retention of the particles at the desired site. This technology can be used for selective damage of tumor cells by hyperthermia or to remove unwanted or excess hair. The maximal depth of particle penetration into the skin achieved in this paper was 0.7 mm.

Keywords: magnetic particles, permanent magnet, and human skin

1. INTRODUCTION

The use of magnetic microspheres in various fields of biology and medicine attracts a great interest of researchers. The area of application beside diagnostics, cell separation, drug delivery, microsurgical devices, etc. includes hyperthermia. [1-8] The magnetic microspheres are injected intraarterially and a special rare earth magnet is then able to stop and concentrate the magnetic in the tumor region. The magnetic particles are pulled out of the blood vessels into the interstitial space and stay at the place of application.[2] Magnetic coupling between the magnetic particles and external field is very selective, which yields controllable temperature elevations in tissue. Thermosensitive property of magnetic particles is used for selective tumor damage.[1-8]

We use an externally positioned magnet to create localized magnetic field within the body. The physical force created by the magnetic field induces transport of the magnetic particles through hair canal and porous, and localization inside the skin. For easement of particle penetration into skin carrier liquids are used. The resulting small depot can be then heated by the magnetic or optical field. Due to selective hyperthermia cells of tumor tissue should be damaged.

To remove unwanted or excess hair, the principles of selective hyperthermia can been employed. That permits the effective treatment of large areas of hair-bearing skin with minimal discomfort and with low risk of scarring or other complications.

We have studied penetration of magnetic particles into the skin due to magnetic field created by magnet concentrator.

2. METHODS AND MATERIALS

In this study we used magnetic powder prepared from inter-metal composition $SmCo_5$. This composition includes 37% of Sm and 63% of Co. The sizes of the particles are in the range 3-5 μm. The homogeneous magnetic suspension was prepared by mixing of magnetic particles and carrier liquid. As a carrier liquid cosmetic lotion #3 of Palomar Medical Products, Inc. and propylene glycol were used.

The magnetic concentrator (see Fig.1) was made from permanent magnet $SmCo_5$ in metal box (1). Maximum of the magnetic field 0.35 Tl is achieved with 25-mm gap between top (3) and bottom (4) magnets. This gap is adjusted by four helixes (2). The concentrator provides a high homogeneity of a magnetic field.

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The experiments were performed *in vitro* with the samples of the human skin. Tissue samples were obtained within a day *post mortem*. The human skin samples were cut into pieces with the area about 2×2 cm^2. The thickness of the samples was about 5 mm.

Pre-operative treatment of the skin samples by KOH solution with pH ~11 for softening of tissue was made. The solution was spread on the skin surface. Time of action was from 5 to 15 min. Then the solution was deleted and the magnet suspension was spread on the surface of the sample.

After that the samples were placed into the center of magnet concentrator (Fig.1). Time of magnet field action on the samples varied from 15 min to 1 hour. Then magnet suspension was deleted thoroughly and samples were put into fixing solution on 24 hours. Prepared samples were frozen and cut into pieces by microtome. Thickness of the pieces was about 5 μm. Part of the samples was dyed by standard dye hematoxiline-eosine. Part of them was not dyed. All these tissue samples were put into immersion liquid and placed between subject glasses.

Optical imaging microscopy was used for investigation of the tissue samples. Photos of all samples were made by the system composed of a microscope and photocamera. Magnifications of the system was 100 or 400.

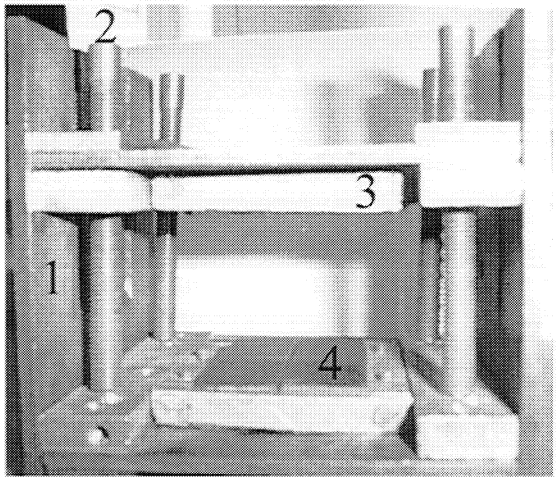

Figure 1. Photo of magnet concentrator: 1 – metal box, 2 – adjusted helixes, 3 – top magnets, and 4 – bottom magnets.

3. RESULTS AND DISCUSSION

In Figs. 2-5 photos of magnificated histological samples of the human skin are shown. Magnetic particles are well seen inside the follicles, sebaceous gland, and sweating gland.

Figures 2 and 3 illustrate the longitudinal sections of non-dyed samples of the skin with hair follicles. Magnetic particles were mixed with Palomar epi-lotion #3. The time of action of magnet was 30 min. In the first case (see Fig.2) the hairs were removed by tweezers before the treatment. In the figure it is seen the fragment of the hair canal with outer root sheath tissue. It is well-seen separate particles and groups of particles inside. The penetration depth of the particles within the follicle is about 0.7 mm. In the Fig. 3 it is seen the hair canal without the hair shaft, which was removed after experiment. Magnetic particles are only in the area of the ostium of the hair canal. The penetration depth of the particles in this case was only 0.3 mm.

Figures 4 and 5 show the cross sections of samples of the skin. The samples were freeze before the dissection and stained by hematoxiline-eosine. Magnetic particles were mixed with propylene glycole. The time of action of magnet was 60 min. Fig. 4 shows the fragment of the sebaceous gland filled up by sebaceous discharge. Magnet particles are inside. In the Fig. 5 it is seen the sweating gland and magnetic particles inside.

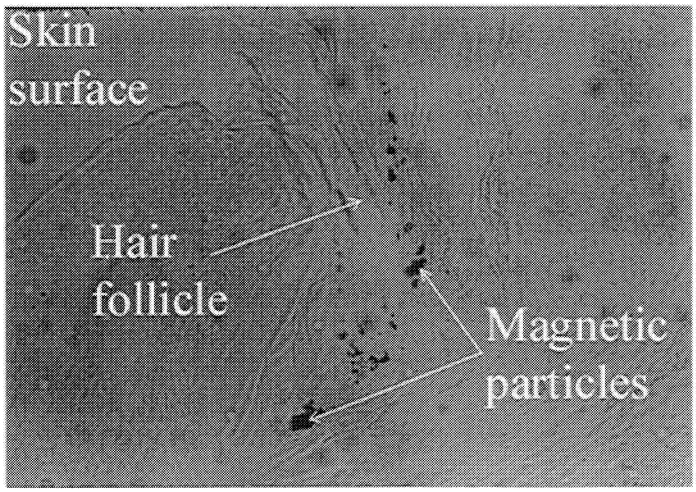

Figure 2. The longitudinal section of non-stained sample of the skin with hair follicle. The hair was removed before the treatment of the skin by magnetic particles. The magnet influence time was 30 minutes. Magnification is 100.

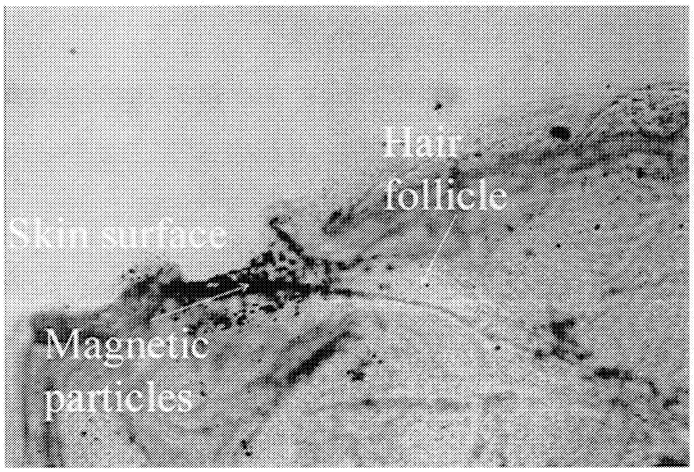

Figure 3. The longitudinal section of non-stained sample of the skin with hair follicle. The hair was removed after the treatment of the skin by magnetic particles. The magnet influence time was 30 minutes. Magnification is 100.

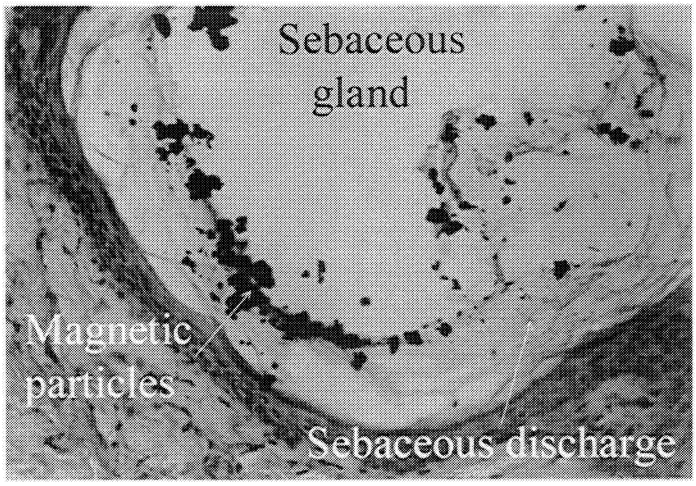

Figure 4. The cross section of the sample of the skin with fragment of sebaceous gland. The sample was freeze before dissection and stained by hematoxiline-eosine. The magnet influence time was 60 minutes. Magnification is 400.

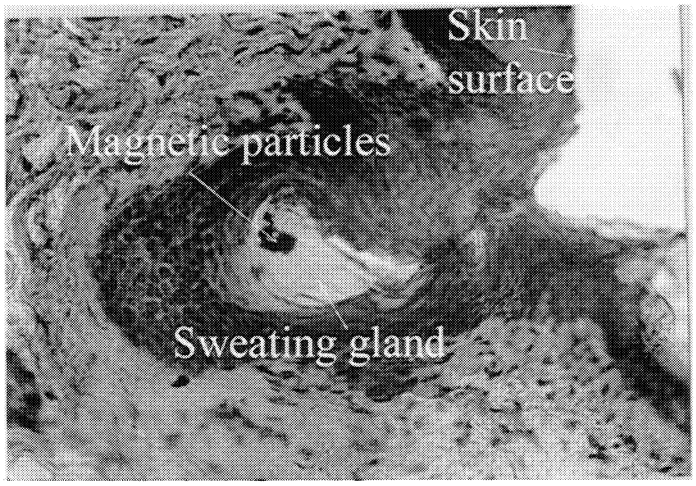

Figure 5. The cross section of the sample of the skin with sweating gland. The sample was freeze before dissection and stained by hematoxiline-eosine. The magnet influence time was 60 minutes. Magnification is 400.

4.CONCLUSION

We studied the penetration of magnetic particles into the human skin *in vitro* under action of permanent magnetic field. In the samples of the human skin with previously epilated hair shafts the depth of particle penetration was about 0.7 mm. In the samples with non-epilated hair the maximum obtained depth was only 0.3 mm. Magnetic particles also penetrates into sebaceous and sweating glands. Intraskin administration of the magnetic particles can be used, for example, for damage of the superficial cancer cells or for removing of unwanted hairs by hyperthermia.

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