Effect of Microdermabrasion on Barrier Capacity of Stratum Corneum

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A new microdermabrasion system is used for peeling the stratum corneum in a controlled manner. The system uses inert corundum powders under various degrees of vacuum. The fine corundum powders ejected by suction power, being quickly in contact with the skin surface, abrade and remove a tiny fragment of stratum corneum. The fraction of the stratum corneum removed by microdermabrasion can be controlled by the operating conditions; the duration of application (*L*) and the degree of vacuum setting (*V*). The stratum corneum barrier function with respect to the rate of skin penetration is well correlated by the product of the square of the degree of the vacuum and the duration of the probe setting.

Key words microdermabrasion; peeling; tape stripping; stratum corneum; viable skin

Controlled microdermabrasion is a methodology which allows to slowly abrade the cutaneous surface, stratum corneum, up to the level desired in a non-traumatic way. The dermabrasion techniques of stratum corneum have been used for the treatment of stretch marks, wrinkles smoothing and acne scars.[1] The controlled dermabrasion can also be applied to estimate the rate of drug penetration across the skin under *in vivo* conditions,[2,3] where the amount of the stratum corneum removed by each dermabrasion treatment must be precisely controlled.[2]

A conventional method for peeling the stratum corneum is tape stripping; the human stratum corneum is reported to be completely removed by about 20 tape stripping.[4,5] The tape stripping is, however, time consuming and the amount of stratum corneum removed may vary in a complicated manner according to the pressure applied by subjects. For the *in vivo* evaluation of the rate of penetration,[2] therefore, the tape stripping technique requires quick and reproducible operation under controlled pressure on the adhesive tape. This is not practical to be carried out in a simple tape stripping operation.

In order to overcome the difficulty associated with the tape stripping method, we have attempted to apply controlled microdermabrasion for removing the stratum corneum, quickly, simply and reproducibly. In the present microdermabrasion, the stratum corneum can be peeled partly or completely according to the number of treatment or the setting time of the probe of microdermabrasion on the skin surface. It is also possible to control precisely the amount of the stratum corneum removed by each treatment, and therefore we can avoid the damage of viable tissue due to over-treatment.

In the present paper, we have investigated the relationship between the barrier capacity of the stratum corneum, which can be defined as the rate of drug penetration, and the operating conditions of microdermabrasion of the skin. The enhancement in the rate of penetration by skin treatment is measured as a function of the number of the treatment or the setting time of the probe for microdermabrasion. The rate of skin penetration following the treatment is also compared with those obtained in a conventional tape stripped skin.

Experimental

A microdermabrasion system, PEPITA (Fig. 1, Mattioli Engineering, Florence, Italy, Inter Face Co. Tokyo, Japan) was used for peeling the stratum corneum. It has been widely used in Europe and recently received FDA approval for use in the United States. PEPITA is a new device that allows the projection of a flow of inert corundum crystals on the skin through a controlled graduated vacuum.[6] The fine corundum particles, being quickly in contact with the skin surface, abrade and remove the stratum corneum, either partly or completely, without damaging the deeper layer of the viable skin.

Immediately after sacrificing the animal, a hand piece whose tip is pierced by a small elliptical hole (approximately 4.5×9 mm) (Fig. 1) was placed on the surface of the dorsal skin of hairless mouse (Hr/Kud, Female, 7w) for 5, 10, 15 or 30 s under the suction power of 0.15, 0.20 or 0.30 bar. Due to a small area of the hole, we assume that the stratum corneum is peeled homogeneously over the opening of the hand piece. The skin treated by PEPITA was then excised to place in the *in vitro* side-by-side diffusion cell[7] for measuring the rate of penetration of a model drug, 17β-estradiol. We found previously that the model drug is negligibly bound in the skin.[8] The concentration of the drug was assayed by HPLC procedure.[9] A matrix-type transdermal delivery system for the drug, fabricated by EVA copolymer membrane with the drug (5% by weight) homogeneously distributed, was then placed on the skin for *in vitro* penetration experiment. Instead of setting the PEPITA probe on the skin, the microdermabrasion was also applied by moving the hand piece of PEPITA (Fig. 1) gently (at about 2 cm/s) on the skin to compare with the probe setting method. The skin treated by the probe moving method was also used to carry out the *in vitro* penetration experiment. The *in vitro* skin penetration experiment after tape stripping was also carried out for comparison.

Results and Discussion

The time course of the cumulative amount of estradiol penetrated, *Q*, after microdermabrasion treatment is shown in Fig. 2, where the profiles for the intact skin and for tape stripped skin are also plotted as dashed lines for comparison. When the rate of penetration is higher initially, the linear portion in the *Q vs.* time profiles becomes shorter since the drug concentration on the surface of the skin decreases more

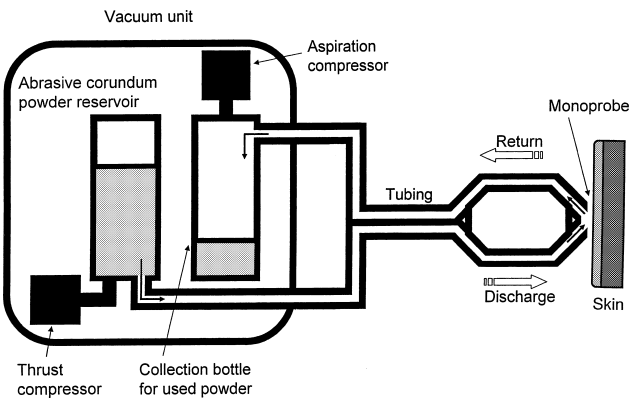

Fig. 1. Microdermabrasion System, PEPITA, Used in This Study

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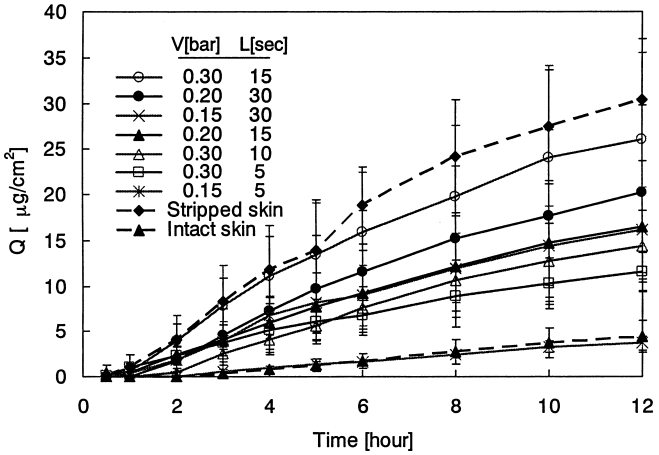

Fig. 2. Cumulative Amount of Estradiol Penetrated after Microdermabrasion with Various Degree of Vacuum (Suction Power) V [bar] and Setting Time of Probe L [s]

The intact and stripped skin data are also shown as dashed lines for comparison.

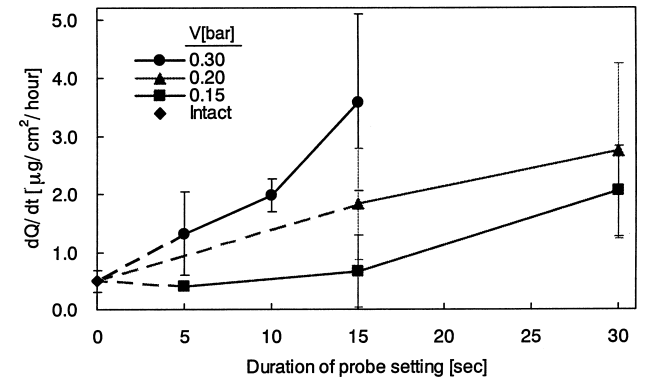

Fig. 3. Effect of Duration of the Probe Setting on the Rate of Skin Penetration

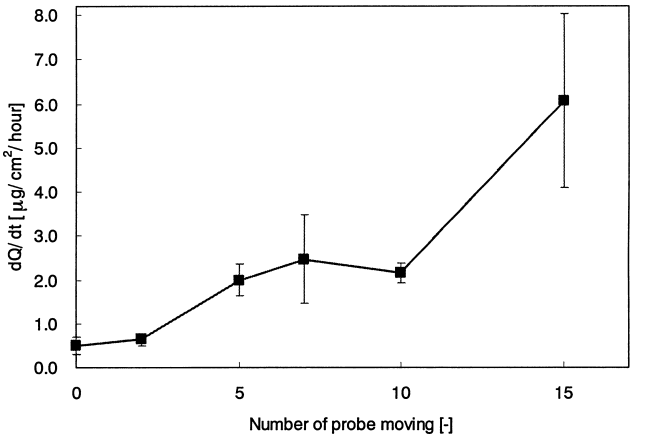

Fig. 4. Effect of Number of Treatment by Probe Movement at 2 cm/s on the Rate of Skin Penetration

V=0.30 bar.

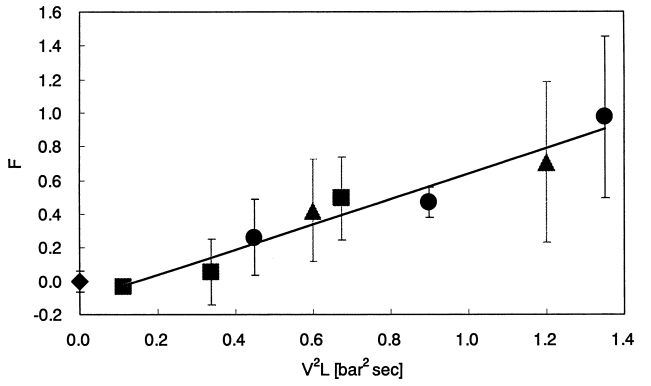

Fig. 5. Effect of the Quantity of V^2L on the Fraction of the Stratum Corneum Removed

Key: (■) V=0.15 bar, (▲) V=0.20 bar, (●) V=0.30 bar, (◆) intact skin. Line: Eq. 2. r^2=0.94.

rapidly because of the increased difficulty in supplying the drug molecules on the surface of the skin. We therefore analyze the Q *vs.* time profile during the initial 6 to 8 h for microdermabrasion treated skin to evaluate the characteristic flux, dQ/dt.

Figure 3 shows the effect of the duration of the probe setting on the rate of skin penetration, dQ/dt. The rate of penetration is approximately proportional to the duration of probe setting when the duration is longer than 5 s. It is found that the stratum corneum can be partially removed in a controlled and predictable manner by adjusting the duration of the probe setting and the degree of vacuum setting (suction power).

Instead of setting the PEPITA probe on the skin surface, the hand piece was repeatedly moved slowly (about 2 cm/s) at the vacuum setting of 0.30 bar on the skin. After carrying out the *in vitro* penetration experiment, the effect of the number of probe moving on the rate of drug penetration was compared to that of the duration of probe setting. The penetration rate was plotted as a function of the number of moving in Fig. 4. It is interesting to see that the number of the treatment by hand piece moving approximately corresponds to the duration of probe setting in seconds on the skin.

The fraction of the stratum corneum removed, F, by PEPITA treatment can be evaluated as follows:

$$F = \frac{\text{Flux}_{\text{treated skin}} - \text{Flux}_{\text{intact skin}}}{\text{Flux}_{\text{stripped skin}} - \text{Flux}_{\text{intact skin}}} \quad (1)$$

where the value of F is 0 and 1 for the intact skin and for the stripped skin, respectively. We assume that the fraction F is influenced by the air flow rate in the tube of equipment (Fig. 1). For compressed air, the average flow rate in a tube is proportional to the square of the pressure difference which corresponds to the suction power V [bar].[10] The fraction F is also proportional to the duration of the probe setting on the skin L [s]. Therefore the fraction F can be correlated with the product of V^2 and L.

Figure 5 shows the fraction, F, as a function of V^2L. As can be seen, the fraction is well correlated with the product of the square of the degree of vacuum V [bar] and the duration of the probe setting L [s]. The fraction of the stratum corneum of the hairless mouse skin removed by PEPITA operation can then be correlated by the following empirical equation:

$$F = 0.75V^2L - 0.11 \quad (2)$$

The above equation can be used within the range of V^2L from 0.1 to 1.4 [bar^2 s]. When V^2L is beyond 1.4, the viable skin would be appreciably removed by PEPITA operation.

By taking account of the difference in stratum corneum

thickness between human skin (20 μm) and hairless mouse skin (10 μm),[2] the fraction of the human stratum corneum removed by the present microdermabrasion is approximately half of the hairless mouse skin. The present microdermabrasion technique will be used in evaluating the *in vivo* skin penetration rate in our future study.

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