Skin Capacitance Imaging for Surface Profiles and Dynamic Water Concentration Measurements

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Introduction

Previous studies show that capacitance based Fingerprint card sensors, originally designed for fingerprint imaging, can be used for skin hydration imaging, surface analysis, and skin micro relief measurements[1-3]. In this paper, we present our latest work on stratum corneum (SC) dynamic water concentration measurements by using Fingerprint card sensors. To further validate the measurement results, we will also compare the Fingerprint card sensors results with SC surface hydration results measured by using opto-thermal transient emission radiometry (OTTER) [4,5] and TEWL (trans-epidermal water loss) results measured by using condenser-chamber TEWL method [6,7].

Apparatus

A hand-held probe, based on the FingerPrint Cards area sensor development kit (FPC-AMD FPC6410), has been developed and used in this research, see Figure 1. It contains a FPC AMD array area sensor chip, a processor board, and a USB connecting cable for connecting to a PC. A dedicated VC++ software has also been developed, which can capture the images, process the images, perform grayscale value calculation, and display the images.

The area sensor chip unit has an array of 152 by 200 capacitive sensors, which generates a 30400 pixels black and white skin capacitance image with a 50x50um special resolution. In the images, each pixel is represented by an 8 bit grayscale value, 0~255, with 0 represent white (low capacitance) and 255 represent black (high capacitance). The image data are saved in standard RAW image format files.

The average grayscale value and its standard deviation of an image are calculated by averaging all the pixel values which are above a certain threshold.

Figure 1. The hand-held probe based on FingerPrint Cards area sensor development kit.

Results and Discussions

All the measurements are performed under normal ambient laboratory conditions, i.e. 21°C, and 40% relative humidity (RH), and all the volunteers are acclimatized in the laboratory for 20 minutes prior to the measurements. The skin sites used for the measurements are untreated, but were wiped clean with ETOH/H_2O (95/5) solution. SC dynamic water distribution is achieved by immersing test skin sites in room temperature water for 20 minutes, three skin sites (face, thumb and volar forearm) are studied, and measurements are performed both before and periodically thereafter.

Figure 2 shows the capacitive images of the three skin test sites before and after the immersive hydration.

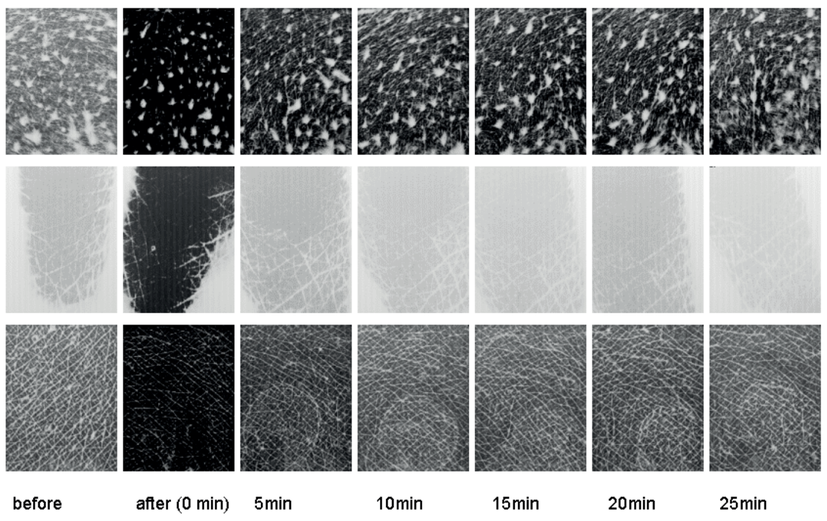

Figure 2. The capacitive images of three different skin sites (from top: face, thumb and volar forear) before and after a 20-minute immersive hydration.

Figure 3 shows the grayscale values of the skin capacitance images of all three skin test sites. The results show that thumb skin site has the most significant hydration increase during the immersive hydration, it is also the quickest to recover to its normal hydration level. While face and volar forearm skin sites have also hydration increases, the face skin site is the slowest to recover. The different dynamic water distributions reflect different skin sites' different characteristics, such as SC water holding/binding capabilities and its barrier functions.

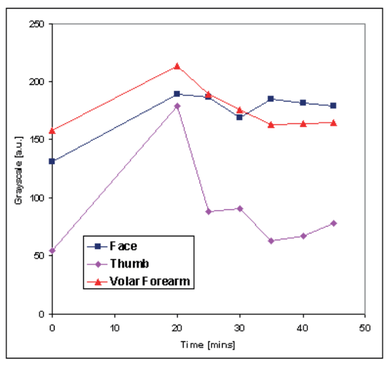

FIGURE 3. SC surface water concentration and water concentration gradient of four different volunteers at nine different skin sites.

Assuming all the pixels whose grayscale values are above the threshold have a good skin contact, by capping their grayscale values we can then produce 3D skin surface profiles. Figure 4 shows the 3D skin surface profiles of three skin sites before and after the immersive hydration by using the image data shown in Figure 2.

To further validate the grayscale values from the capacitive skin images, we also performed the opto-thermal transient emission radiometry (OTTER) and condenser-chamber TEWL method measurements at the same time. Figure 5 shows the skin surface hydration results before and after the immersive hydration and Figure 6 show the TEWL value results. The skin surface hydration results are general in agreement with the grayscale value results.

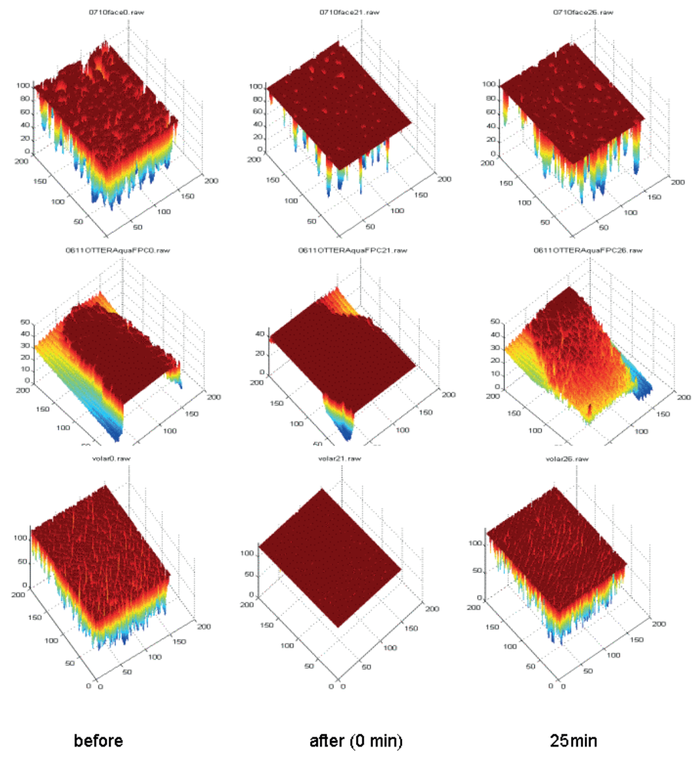

Figure 4. The 3D skin surface profiles of three different skin sites (from top: face, thumb and volar forearm) before and after a 20-minute immersive hydration.

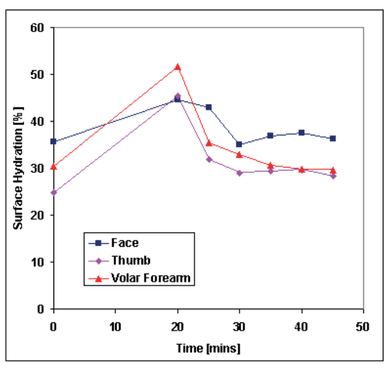

Figure 5. SC surface water concentration of three different skin sites before and after a 20-minute immersive hydration by using OTTER.

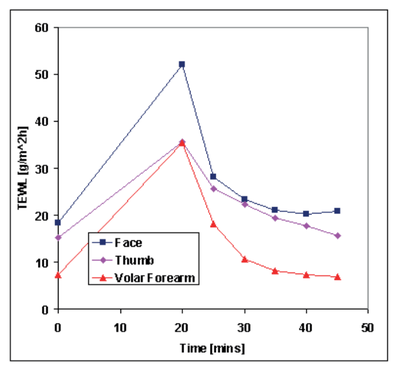

Figure 6. SC TEWL values of three different skin sites before and after a 20-minute immersive hydration by using condenser-chamber TEWL method.

Figure 7 shows the correlation between SC surface hydration [%] and grayscale values and Figure 8 shows the correlation between grayscale values and TEWL values. Different skin sites clearly have different correlations which reflects the different SC characteristics. With data shown in Figure 7 we can now convert the grayscale values into hydration levels.

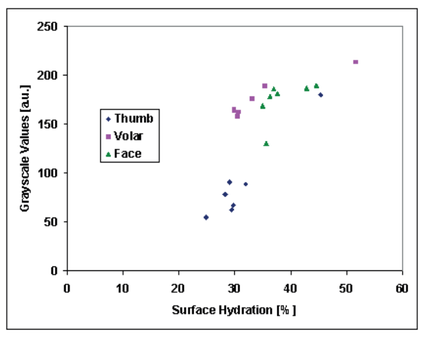

Figure 7. The correlation between SC surface water concentration and grayscale values.

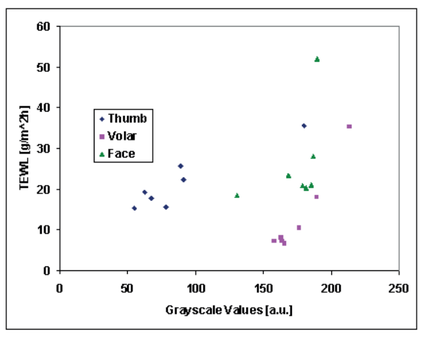

Figure 8. The correlation between grayscale values and TEWL values.

Conclusions

The study shows that the Fingerprint card sensors can be used for measuring SC dynamic water concentration. The grayscale values of the SC capacitive images show that different skin sites react differently to the immersive hydration even under identical conditions. With these capacitive images we can also get the skin surface 3D profile and show how they change before and after the immersive hydration. Comparing with opto-thermal transient emission radiometry (OTTER) results and condenser-chamber TEWL (trans-epidermal water loss) method results, we can also calibrate the grayscale values of the images.

Acknowledgement

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References

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