Opto-thermal in-vivo skin hydration measurements – a comparison study of different measurement techniques

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Opto-thermal in-vivo skin hydration measurements - a comparison study of different measurement techniques

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Abstract. We compared five different skin hydration measurement techniques, namely OTTER, Fingerprint sensors, Corneometer, Nova, and Moisture Checker, in order to understand the correlations between different skin hydration measurement techniques and to understand the repeatability of each technique. The measurements are performed on different in-vivo skin sites from different volunteers and at different hydration levels. The repeatability of different techniques is achieved by measuring the same skin site repeatedly. The correlations between different skin hydration measurement techniques are achieved by plotting results from different techniques against each other. The different skin hydration levels are achieved through the recovery period after a skin immersive hydration.

1. Introduction

Stratum corneum (SC) is the outmost human skin layer which is made of layers of flat, polyhedral dead cells filled with keratin. Water concentration and its distribution depth profile within SC play a key role in skin cosmetic properties as well as its barrier functions. However, to measure skin hydration, especially to confine the measurements within SC is very difficult [1,2]. Opto-thermal transient emission radiometry (OTTER) [3,4] is an infrared remote sensing technology that can be easily confined within SC by selecting water absorption peaks as excitation and detection wavelengths. The detection depth is typically within top 20 µm of skin, well within SC. OTTER works on arbitrary, unprepared skin surfaces, and it is a truly non-contact, non-invasive technology that can be potentially used for in-vivo skin routine test in the areas of SC hydration measurements, SC hydration depth profiling measurements, and trans-dermal drug delivery measurements [5,6]. Recently, capacitance based Fingerprint sensors, originally designed for fingerprint imaging, have also show potentials in skin hydration imaging, surface analysis, 3D surface profiles, and skin micro relief measurements [7,8]. In this paper, we compare OTTER and Fingerprint sensors with other existing skin hydration measurement techniques, such as Corneometer, Nova, and Moisture Checker, in order to study the correlations between different skin hydration measurement techniques and to understand the repeatability of each technique.

2. Theory

For any measurement instruments, the observed scatter depends on instrument variability and skin variability. Because instrument variability is independent of skin variability, and assuming they follow a normal distribution, then observed scatter (*Vo*) can be described in following relationship with instrument variability (*Vi*) and skin variability (*Vs*), see Eq.(1) and Figure 1. Therefore, when skin variability is small, observed scatter reflects more about the instrument variability, and vice verse.

$$Vo^2 = Vi^2 + Vs^2 \tag{1}$$

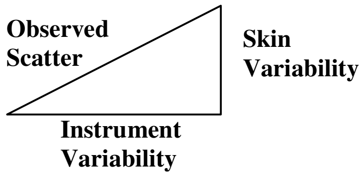

Figure 1. The relationship between observed scatter, instrument variability and skin variability.

3. Apparatus

Five skin hydration measurement instruments - opto-thermal transient emission radiometry (OTTER), Fingerprint sensor (MBF200, Fijistu), Corneometer (CM825, C+K Electronic) [1], Nova (DPM 9003, DermLab) [1] and Moisture Checker (Scalar) [9]- are used to measure in-vivo skin hydration of different skin sites from different volunteers and at different hydration levels. OTTER is an infrared technology that uses a pulsed laser as heat source to heat up the skin, and a fast infrared detector to pick up the consequent blackbody radiation signal. The measurement results are shown as percentage of water. Fingerprint sensor uses a matrix (256x300) of capacitance sensors to generate a 2D skin image with 50μm special resolution, the measurement values are displayed as 8 bit grayscale values. Corneometer is a capacitance based technology which uses closely spaced parallel gold lines as capacitor plates to measure the capacitances of skin. Nova DPM is an impedance-based instrument which allows impedance-based capacitance readings by integrating measurements at different frequencies of the applied alternating current. For both Corneometer and Nova DPM, hydration values are expressed in arbitrary units. Moisture checker uses a capacitance sensor to measure the permittivity of the skin, hydration values are expressed as percentage of water.

4. Results and Discussions

All the measurements are performed under normal ambient laboratory conditions, i.e. 20~21°C, and 40~50% 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.

4.1. Repeatability

The repeatability measurements are done by measuring the same skin site repeatedly 30 times using five different measurement instruments. Totally seven different skin sites were studied. Table 1 shows the repeatability study results in the format of the average, the standard deviation (StDev), and the coefficient of variation (CV). As illustrated in section 2, the variability in measurement results reflect both skin variability and instrument variability, and we can not completely separate the two. However, according to Eq.(1), by calculating the root mean square (RMS) of the coefficients of variation of different instruments on the same skin site, we can minimize the instrument variability, get more information skin variability; whilst by calculating the root mean square (RMS) of the coefficients of variation of different skin sites with the same instrument, we can minimize the skin variability and get more information on instrument variability. The skin variability results show that skin sites from palm and volar forearm are the least variable sites, and the instrument variability results show that OTTER and moisture checker gave the most repeatable results. The high variability in Fingerprint sensor results is likely due to in-consistent contact pressure. Work is in progress to develop a new measurement case which will maintain a constant contact pressure during measurements.

Table 1 The repeatability study results of different skin sites using different measurement instruments.

	Fingerprint			OTTER			Corneometer			Moist Checker			Nova			Skin
	Average:	StDev:	CV:	Average:	StDev:	CV:	Average:	StDev:	CV:	Average:	StDev:	CV:	Average:	StDev:	CV:	**Variability**
Palm	78.4	4.4	5.6%	24.2	0.3	1.3%	33.5	1.7	4.9%	30.2	1.1	3.5%	167.5	7.8	4.6%	**4.3%**
Thumb	129.4	9.9	7.7%	25.2	0.4	1.4%	40.9	2.6	6.4%	33.9	1.0	2.9%	501.3	21.4	4.3%	**5.1%**
Volar Forearm	75.8	5.4	7.1%	25.2	1.2	4.7%	37.1	1.5	4.2%	30.3	0.8	2.7%	178.0	4.7	2.6%	**4.6%**
Forehead	74.6	8.5	11.4%	26.7	1.0	3.9%	47.3	4.4	9.2%	31.7	1.4	4.4%	147.5	4.8	3.2%	**7.2%**
Neck	80.9	11.1	13.8%	31.3	1.9	6.0%	53.6	3.8	7.1%	30.5	1.7	5.6%	170.3	14.0	8.2%	**8.7%**
Cheek	52.3	5.8	11.1%	32.3	1.1	3.3%	39.4	3.2	8.1%	22.2	2.4	10.9%	126.3	14.7	11.6%	**9.5%**
Back of Hand	70.1	2.6	3.7%	27.7	0.8	2.9%	40.2	4.5	11.1%	31.4	0.8	2.4%	203.4	4.8	2.3%	**5.6%**
Instrument Variability			**9.2%**			**3.7%**			**7.6%**			**5.4%**			**6.2%**	

Figure 2 shows Table 1's coefficient of variation (CV) results and correlations of between OTTER and other measurement instruments. Apparently the correlations between each measurement instrument are very poor, this is because instrument variability is comparable with skin variability, the measurements results are dominated by the instrument variability.

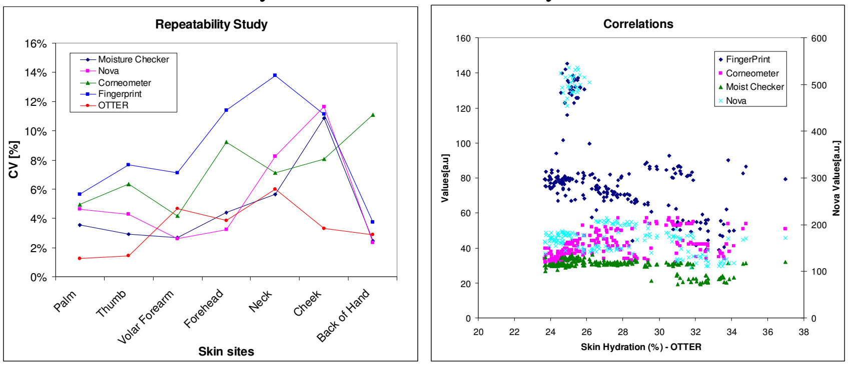

Figure 2. Coefficient of variation (CV) results of different skin sites using different measurement instruments (left) and correlations of different measurement instruments (right).

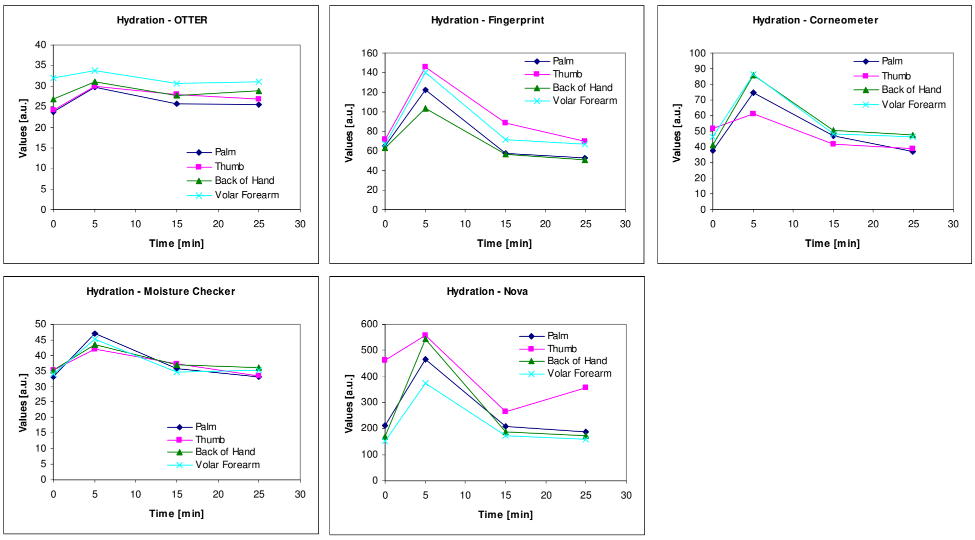

Figure 3. The wet tissue patch hydration measurement results of five different measurement instruments on four different skin sites.

4.2. Correlations

In order to study the correlations of the different measurement instruments, we need to increase the skin hydration levels. The increasing of skin hydration levels in this study is achieved through skin occlusion by applying a wet tissue patch on test skin sites for 5 minutes. The measurements were performed both before and after the occlusions.

Figure 3 shows the wet tissue patch hydration measurement results of four different skin sites by using five different measurement instruments. For all five measurement instruments, the skin hydration level increased immediately after the 5 minutes wet tissue patch occlusions, and gradually recovered back to the normal levels after about 20 minutes. Figure 4 shows the correlation between OTTER/Fingerprint sensors and other measurement instruments. In this case, there is a general good correlation between OTTER/Fingerprint sensor and all other measurement instruments.

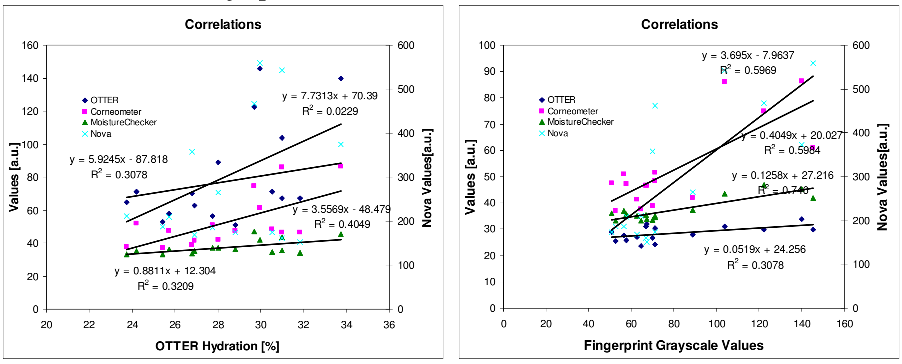

Figure 4. The correlations between different measurement instruments.

5. Conclusions and Future Work

The study shows that by repeatedly measuring different skin sites using different measurement instruments, we can study the skin site variability and the instrument variability. By measuring different skin hydration levels using different measurement instruments, we can study the correlations between each measurement instrument. The results show that there is a general good correlation between OTTER/Fingerprint sensor and all other measurement instruments.

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