

Tissue Dielectric Constant (TDC) as an Index of Skin Water in Women with and without Breast Cancer: Upper Limb Assessment via a Self-Contained Compact Measurement Device

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Background and Goals

The goal of this study was to assess the applicability and potential limitations of a compact hand-held device that measures skin tissue dielectric constant (TDC) and to provide reference values for different age groups and anatomical locations. Prior work has shown TDC measurements made at 300 MHz, using either a multiprobe system or a compact device, accurately reflect local skin water values and their change. The specific aims of the present study were to use the compact hand-held version to 1) evaluate its utility in assessing age-related differences between younger healthy women vs. women with unilateral breast cancer (BC) 2) Determine arm site differences in women with BC and 3) assess the utility and limitations of single measurement vs averaging triplicate measurements.

Methods (Subjects)

Subjects consisted of two groups: Group A included 42 self-described healthy adult women age 18-29 years old (24 ± 2.4); Group B included 42 adult women age 43-87 years old (65.5 ± 1.6) with unilateral BC prior to treatment. In both groups bilateral TDC measurements were made on the anterior forearm (Fig 1b). In addition, bilateral hand (Fig 1c) and bicep (Fig 1a) single and triplicate measurements were made for women included in group B.

Methods (TDC Measurement)

The measurement is based on the principle that the TDC is directly related to the amount of free and bound water contained in the measuring volume (Fig 3). The device used in this study was the hand-held compact device (MMDC) manufactured by Delfin Technologies (Kuopio, Finland) as shown in Fig 2. The TDC of specific target areas was determined using a gentle skin contact for about 8 seconds. Prior work has indicated that the effective penetration depth of the compact device is close to 2.5 mm. The measurement output is the TDC value that has a range of 1 to 80. For reference, water at a temperature of 34°C has a value of about 76.

Measurement Procedures

The 84 women in this study were evaluated and fulfilled entrance requirements after signing a University IRB approved informed consent. Measurements were done with subjects seated and began after a 10 minute acclimation rest interval. TDC values were measured bilaterally at three sites: Groups A and B were both measured on the anterior forearm, 6 cm distal to the antecubital crease (Fig 1b). Group B was also measured on the hand dorsum between thumb and index finger and on the anterior biceps 8 cm proximal to antecubital crease (Figs 1a and 1c).

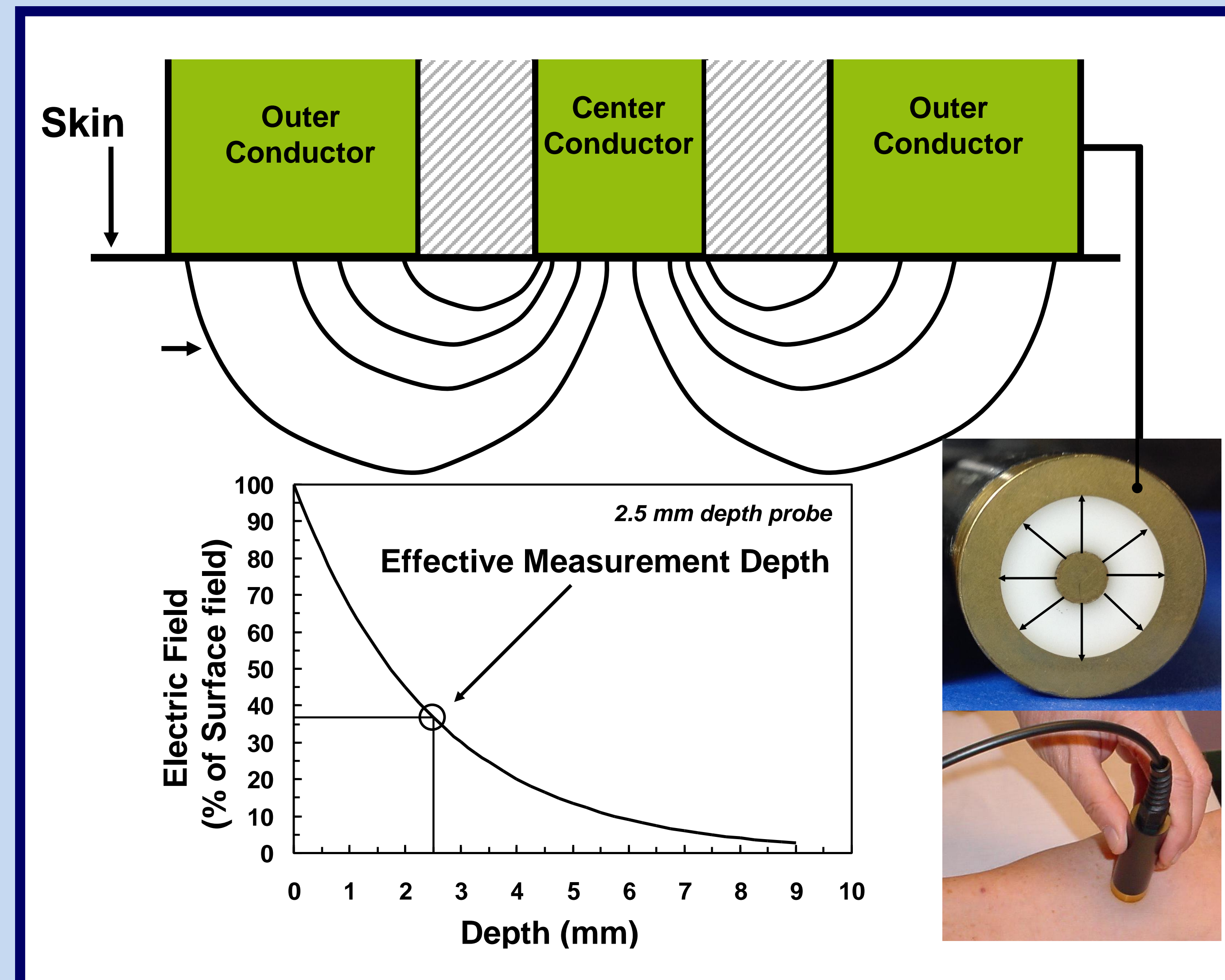
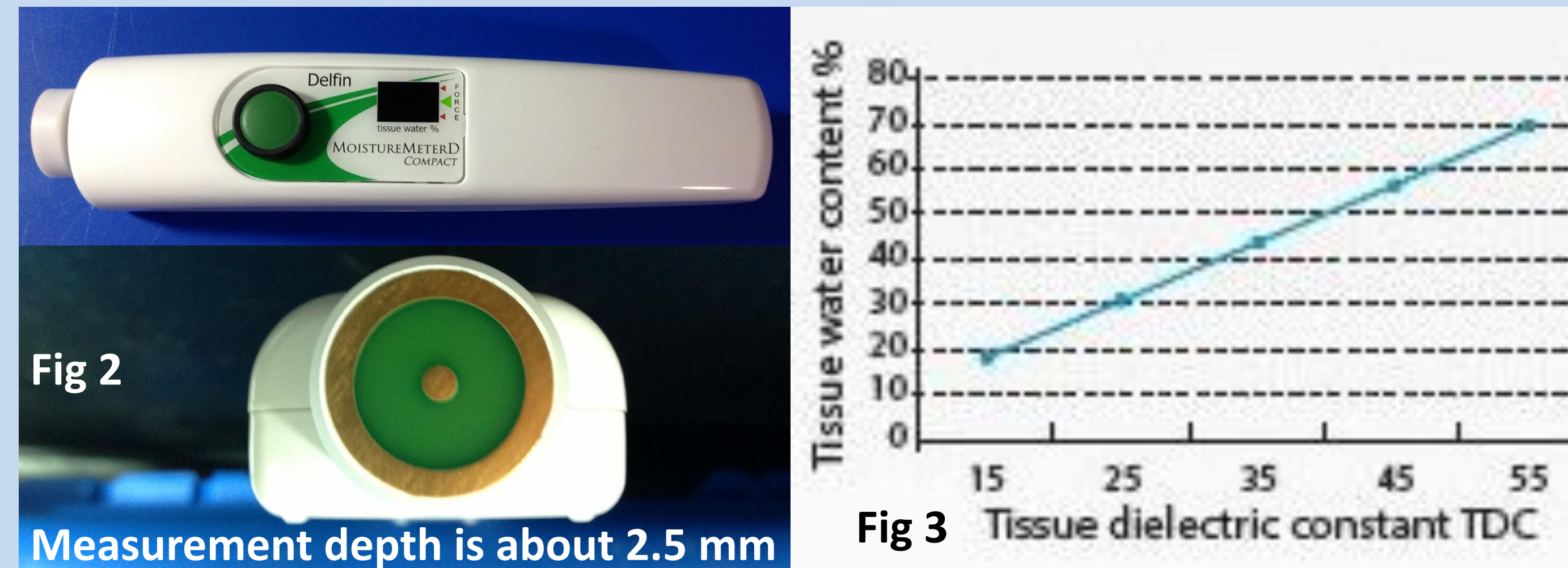
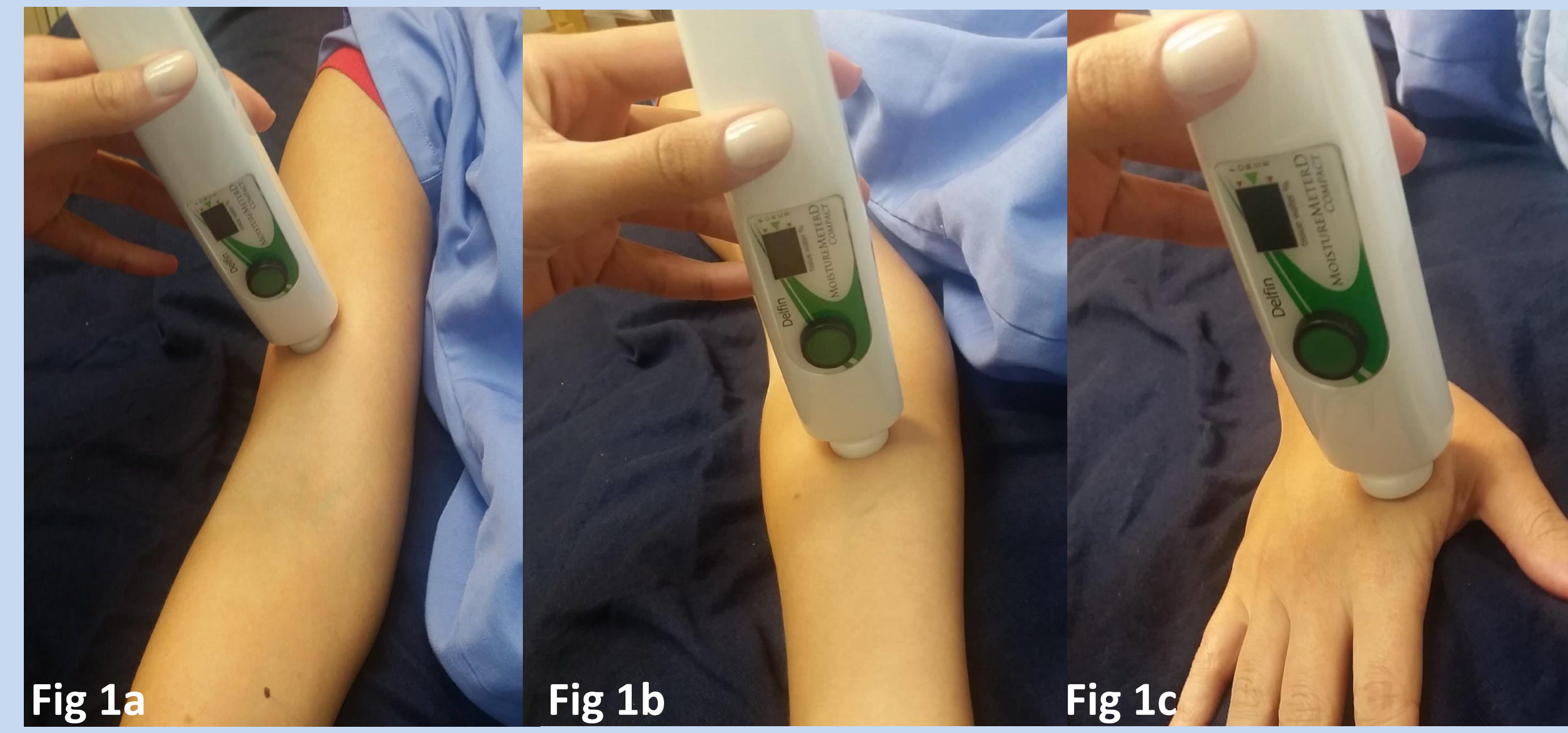
Analyses

Age related differences (Group A and B) The average of triplicate TDC values at each site, denoted as TDC3, was used to characterize each site's TDC value. TDC_{AVG} is calculated from the average dominant and non-dominant TDC3 values.

Variations among sites (Group B) Comparisons of TDC values was done via analysis of variance (ANOVA) using TDC values for at-risk and contralateral arms separately. Post-hoc comparisons to assess differences between sites were done using the Bonferroni adjustment.

Average TDC values vs Single TDC value (Group B) Absolute difference $\delta = (TDC1 - TDC3)$ was used for TDC3 and TDC1 comparisons.

Measurements Illustrated



Illustrating the approximate field lines and effective measurement depth for a coaxial probe TDC measurement. The Device shown is the multiprobe version But the principal is the same for the compact version.

Main Results

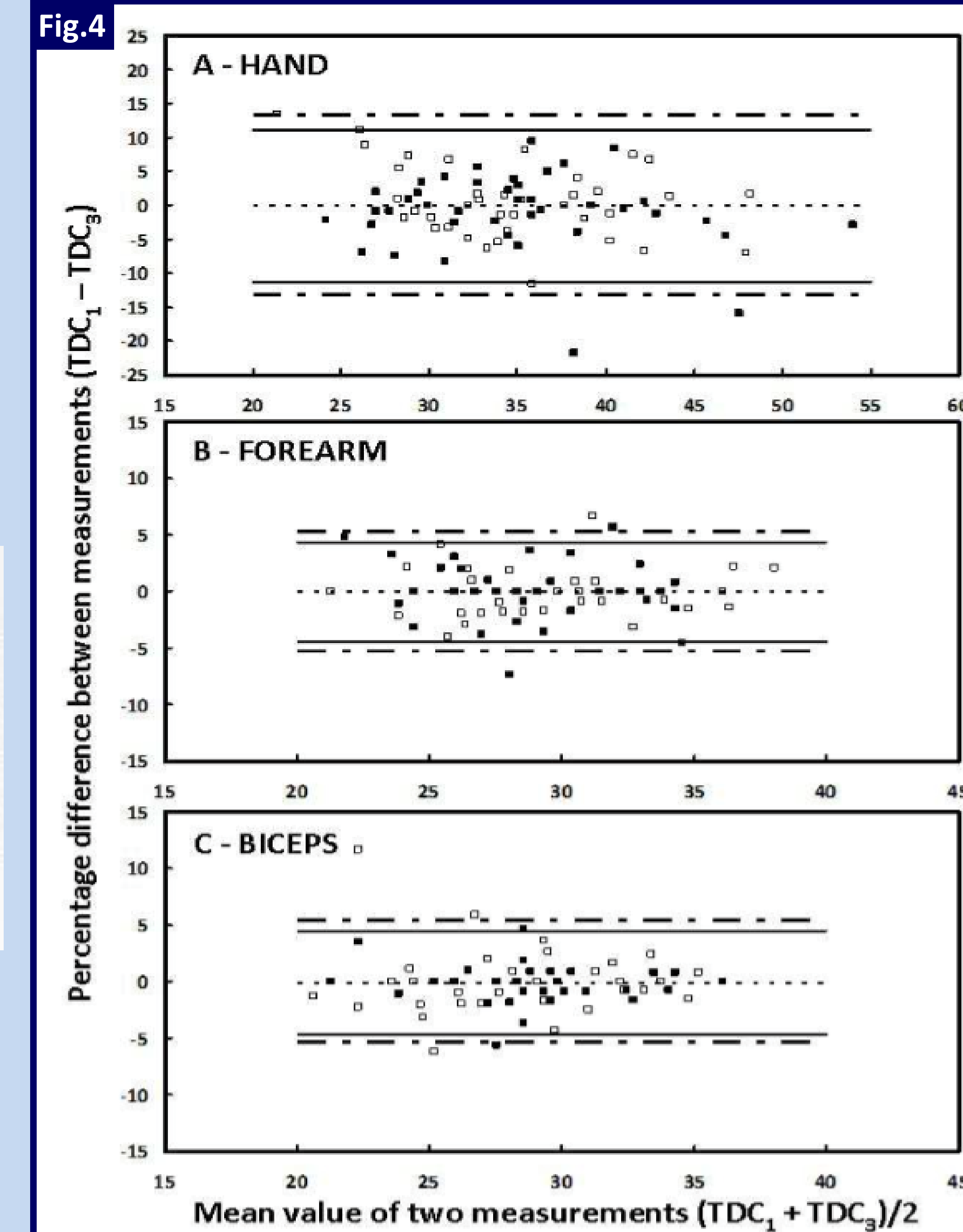


TABLE 1	Group A (N=42)	Group B (N=42)	p-value
Age (Years)	24.0 ± 2.4	65.5 ± 1.6	0.0001
BMI (Kg/m ²)	23.5 ± 4.6	28.0 ± 5.2	0.001
TDC _{AVG}	28.5 ± 3.5	29.2 ± 3.5	0.332
TDC _{RATIO}	0.999 ± 0.050	0.989 ± 0.068	0.480
Girth _{AVG} (cm)	23.1 ± 2.3	23.3 ± 2.9	0.844
Girth _{RATIO}	1.017 ± 0.027	1.020 ± 0.026	0.643

Fig 4 is a Bland-Altman plot showing differences between single and averaged TDC for women with breast cancer. The central dashed line is the mean value of the difference, the solid upper and lower lines are located at $\pm 2SD$ from the mean and define the limits of agreement (LOA) and the line (long-dash, short-dash) above and below the LOA are the upper and lower 95% confidence intervals on the LOA. Open squares are data for contralateral arms and closed squares are data for at-risk arms.

Results Summary:

Age related differences (Groups A and B) except for greater BMI of group B (table 1) all other measured forearm parameters were similar between groups with the average dominant and non-dominant TDC values (TDC_{AVG}) between groups being 2.4% with group B insignificantly greater.

There were no group differences in the inter-arm ratios of either TDC_{RATIO} or Girth_{RATIO}. TDC values for dominant vs. non-dominant forearms were not significantly different between arms for group A (28.5 ± 1.9 vs. 28.5 ± 2.1 , $p = 0.850$) or for group B (29.0 ± 3.5 vs. 29.4 ± 3.5 , $p = 0.225$). TDC values for corresponding arms were not significantly different between groups for the dominant arm ($p = 0.570$) or non-dominant arm ($p = 0.300$).

Variations among sites (Group B)

Hand TDC values were found to be significantly greater ($p < 0.001$) than forearm and biceps (Table 1) being about 20%-22% greater than each, while forearm and biceps were similar and not significantly different. Inter-arm TDC ratios (at-risk arm/contralateral arm) were similar among all three sites being 1.027 ± 0.180 at the hand, 0.997 ± 0.066 at the forearm and 1.010 ± 0.075 at the biceps.

Average TDC values vs Single TDC value (Group B)

Triplicate averaged TDC values (TDC3) did not significantly differ from first TDC measurements (TDC1) on at-risk or contralateral arms at any site (Table 1).

Conclusions

- 1) Forearm TDC values are similar for younger and older groups with no significant differences between groups or between dominant and non-dominant sides or inter-arm ratios.
- 2) Hand TDC values are about 21% greater than forearm and biceps values but inter-arm ratios are not significantly different among sites.
- 3) Single TDC measurements are likely adequate for most forearm and biceps evaluations but multiple measurements would be indicated for hand TDC evaluations.
- 4) The compact TDC device is well suited to the rapid assessment of skin tissue