Validation of Commercially Available Infrared Thermometers for Measuring Skin Surface Temperature Associated with Deep and Surrounding Wound Infection

Asfandyar Mufti, BMSc; Patricia Coutts, RN; and R. Gary Sibbald, BSc, MD, MEd, FRCP(C)(Med)(Derm), MACP, FAAD, MAPWCA, DSc(Hons)

ABSTRACT

OBJECTIVE: Increased local skin temperature is a classic sign of wound infection, repetitive trauma, and deep inflammation. Noncontact infrared thermometers can help to detect increases in skin surface temperatures; however, most scientifically tested devices are far too expensive for everyday wound care providers to use in routine clinical practice. This noninferiority study was conducted in an attempt to determine whether 4 less expensive, commercially available noncontact infrared thermometers have a similar level of accuracy as the scientifically accepted Exergen DermaTemp 1001 (Exergen Products, Watertown, Massachusetts).

DESIGN, SETTING, AND PARTICIPANTS: Using an observational study design, participants with open wounds were randomly selected from a chronic wound clinic (n = 108). Demographic data and wound location were documented for all participants. Skin temperatures were recorded using 5 noncontact infrared thermometers under consistent environmental conditions. The thermometer brands were as follows: Exergen DermaTemp, Mastercool MSCS2224-A (Mastercool Inc, Randolph, New Jersey), ATD Tools 70001 Infrared Thermometer (ATD Tools Inc, Wentzville, Missouri), Mastercraft Digital Temperature Reader (Mastercraft Canada, Toronto, Ontario, Canada), and Pro Point Infrared Thermometer (Princess Auto, Winnipeg, Manitoba, Canada). Data analysis was based on the skin surface temperature difference (∆T in degrees Fahrenheit) between the wound site and an equivalent contralateral control site.

OUTCOME MEASURES: One-way analysis of variance was used to compare the mean ∆T values for all the 5 thermometers, followed by post hoc analysis. Demographic data were analyzed using descriptive statistics. Inter-rater reliability was assessed for consistency using the intraclass correlation coefficient.

MAIN RESULTS: No statistical difference was reported between the ∆T values for the 5 different thermometers (F4,514 = 0.339, P = .852). Post hoc analysis showed no significant difference when the thermometers were compared with the Exergen DermaTemp 1001, and Mastercool MSCS2224-A (P = .967), ATD Tools 70001 Infrared Thermometer (P = .985), Mastercraft Digital Temperature Reader (P = .972), and Pro Point Infrared Thermometer (P = .774). The results for intraclass correlation demonstrated a high reliability and agreement between raters, as the intraclass correlation coefficient values for all thermometers were greater than 0.95.

CONCLUSIONS: The results of this study demonstrate that less expensive, industrial-grade noncontact infrared thermometers have reliable temperature readings to identify and quantify the temperature gradients that along with other signs may be associated with deep and surrounding wound infection or tissue injury due to repeated microtrauma.

KEYWORDS: infrared thermometers, wound infection, measuring skin surface temperature

INTRODUCTION/LITERATURE REVIEW

Temperature plays a pivotal role in the body and its outer skin covering to regulate metabolic and homeostatic processes. The skin is the largest body organ that also serves as a barrier against pathogens, contains nerve endings for sensation, acts as storage of lipids and water, controls evaporation, and is involved in thermoregulation. The importance and relationship between body...
surface temperature and disease have been recognized by physicians for centuries. As early as 400 BC, Hippocrates wrote, “In whatever part of the body excess of heat or cold is felt, the disease is there to be discovered.” Changes in body surface temperature can be a sign of infection, repetitive trauma, or deep inflammation, along with less common thromboembolic processes and immune and metabolic disorders.

Studies conducted by Armstrong et al2–4 and Lavery et al5–7 demonstrated the importance of self-monitoring skin temperature in patients with diabetes, especially those at risk for lower-extremity complications. These studies demonstrated that regions of elevated temperature in individuals with diabetic neuropathy were more likely to ulcerate, unless clinicians introduced aggressive preventive strategies including plantar pressure redistribution, contact casts (removable or irremovable), or pneumatic walkers.

More recently, Fierheller and Sibbald8 reported the relationship between increased periwound skin temperature and local wound infection in patients with chronic leg ulcers. Prolonged healing of chronic wounds is a problem that causes tremendous patient distress and discomfort. Furthermore, delayed wound healing increases the risk of additional complications and significantly adds to healthcare costs.9,10

Increased periwound temperature is a classic sign of wound infection and is the most reliable clinical sign of deep and surrounding skin infection, when analyzed with individual factor analysis of the STONEES (size, temperature, os, new, exudate, erythema and edema, smell) criteria.11 The quantitative measurement of skin temperature as part of wound assessment facilitates the monitoring of wound-associated deep and surrounding infection.11 It is important to note, however, that an elevated temperature alone does not necessarily mean that there is an infection. Two or more other clinical features of the STONEES criteria are also needed that include increased size, probing or exposed bone, new areas of breakdown, erythema/edema = cellulitis, and increased exudate or smell.

The diagnostic accuracy of manual finger palpation to determine skin temperature is very limited, especially because it is more subjective than objective.12 Conventional mercury or electronic thermometers are difficult to attach to the wound or periwound skin, need time to be calibrated, and because of incomplete surface contact are prone to inaccurate readings.13 A handheld non–skin contact infrared thermometer has the potential to provide an accurate, objective, and quantitative comparative measurement of skin surface temperature.13

The basic premise behind infrared thermometry is as follows: All objects above the temperature of absolute zero release infrared radiation.14 Heat released by inflammation is a form of infrared radiation. When this infrared radiation hits a sensor in the thermometer, the sensor converts this energy into a specific electrical signal that corresponds to a given temperature. The higher the temperature, the greater the infrared radiation received by the sensor that outputs a larger temperature.

Most skin surface infrared thermometers used in everyday clinical practice are of scientific study quality and too expensive for most healthcare professionals to incorporate into practice. The authors’ goal is to test the accuracy of 4 less expensive commercially available infrared thermometers normally used for industrial machines and automobiles. These thermometers will be compared with the scientifically accepted Exergen DermaTemp 1001 infrared thermometer (Exergen Products, Watertown, Massachusetts) utilized in several peer-reviewed published studies.2–7,15–23

### METHODS AND MATERIALS

An observational study design provided both an economic and simple method for investigation. The Central Ethics Board approval was obtained, and consenting participants were purposefully recruited from within the patient population of a chronic wound clinic using specific inclusion/exclusion criteria. One hundred eight patients (n = 108) with wounds were measured for surface temperature. Demographic data (eg, age, height, weight, gender, and ethnicity) were also collected from all patients. Each limb was measured using 5 different devices (Table 1 and Figures 1 and 2).

1. Exergen DermaTemp 1001;
2. Mastercraft Digital Temperature Reader (Mastercraft Toronto, Ontario, Canada);
3. ATD Tools 700001 Infrared Thermometer;
4. ProPoint Infrared Thermometer;
5. Mastercool MSC52224-A

#### Table 1. INFRARED THERMOMETER SPECIFICATIONS

<table>
<thead>
<tr>
<th>Device</th>
<th>Measurement Range</th>
<th>Operating Range</th>
<th>Accuracy (Ambient Temperature = 25°C)</th>
<th>Distance-to-Size Ratio</th>
<th>Continuous Scanning</th>
<th>“Maximum” Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exergen DermaTemp 1001</td>
<td>18°C to 43°C (65°F to 110°F)</td>
<td>16°C to 43°C (60°F to 110°F)</td>
<td>±0.1°C (0.2°F)</td>
<td>1:1</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Mastercraft Digital</td>
<td>−30°C to 480°C (−22°F to 886°F)</td>
<td>0°C to 50°C (32°F to 122°F)</td>
<td>±2.0°C (4.0°F)</td>
<td>8:1</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Temperature Reader</td>
<td>−60°C to 550°C (−76°F to 1022°F)</td>
<td>0°C to 50°C (32°F to 122°F)</td>
<td>±1.5°C (2.7°F)</td>
<td>12:1</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>ATD Tools 700001 Infrared Thermometer</td>
<td>−60°C to 500°C (−76°F to 932°F)</td>
<td>0°C to 50°C (32°F to 122°F)</td>
<td>±1.0°C (1.8°F)</td>
<td>12:1</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Mastercool MSC52224-A</td>
<td>−58°C to 932°C (−50°F to 950°F)</td>
<td>0°C to 40°C (32°F to 104°F)</td>
<td>±2.0°C (4.0°F)</td>
<td>12:1</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Accuracy at ambient temperature 23°C.*
The Mastercool MSC52224-A was introduced 2 days late into the study and was tested on a total of 87 patients (n = 87) over the course of the study. Under consistent environmental conditions, skin temperature data were obtained from both the target (wound site) and contralateral control sites at a distance of 3 cm above the skin using each of the thermometers for a total of 5 patient recordings.

In the case of wounds located in the sacral region, the authors compared the target temperature with an unwounded area above or below the wound. This was a standard procedure for all wounds that were anatomically located along the midline and did not have a “contralateral” side as a comparator.

Temperature readings were made approximately 10 minutes after removing the wound dressings. This delay was timed to avoid heat collected under occlusive dressings or evaporation artifacts. Using gun-shaped infrared thermometers in this study was easy and intuitive. Once the trigger was depressed, real-time temperature acquisition started. The authors moved the thermometer over and around the wound in a “grid pattern” to ensure that all regions surrounding the wound were covered. The temperature was recorded in degrees Fahrenheit for convenience of detecting temperature differentials. The location of the wound and the contralateral site was also recorded. The target temperature was subtracted from the contralateral temperature, in order to obtain the temperature difference/gradient: \( \Delta T \). To validate the interrater reliability of the thermometer between clinicians, the principal investigator and an experienced wound care nurse duplicated temperature readings independently on 20 participants.

Participants were included if they (1) were 18 years or older, (2) provided written informed consent, (3) participated in 1 study assessment, and (4) had a wound. Participants were excluded if they (1) were younger than 18 years, (2) were unable to consent due to language barrier, or (3) had no current skin ulcer.

**Data Analysis**
Statistical analysis was conducted using SPSS Statistics 22 for Windows (IBM, Armonk, New York). A 1-way analysis of variance compared the mean \( \Delta T \) between the 5 different thermometers.
Post hoc analysis was conducted using Tukey test to compare 4 different thermometers, with the DermaTemp Exergen 1001 as the criterion standard. Interrater reliability of the 5 different thermometers was analyzed using intraclass correlation coefficient. Furthermore, a 2-way mixed model was selected for analysis. The authors used an α level of .05 as the cut-off point for all test significance.

RESULTS
A total of 188 patients (n = 108) participated in the study. The study population consisted of 61 men (n = 61) and 47 women (n = 47). All demographic data were reported by the patient. The mean age ranged from 26 to 94 years (mean, 62.9 [SD, 15.55] years). The weight ranged from 100 to 480 lb (mean, 194.68 [SD, 66.23] lb). The reported height ranged from 60 to 80 inches (mean, 67.93 [SD, 4.32] inches). The wound duration varied from 5 days up to 6 years (mean, 21.49 [SD, 18.2] months). Forty-four percent (n = 47) of the participants were diagnosed with diabetes at the time of their visit. Eighty-nine percent (n = 42) of these patients had type 2 diabetes. The study wounds had a wide variety of etiologies (Figure 3).

A 1-way analysis of variance yielded no significant difference between the 5 different thermometers in regard to the $\Delta T$ value ($F_{4,514} = 0.339, P = .852$). Post hoc analysis using Tukey honest significant difference indicated that the DermaTemp thermometer did not have a significantly different $\Delta T$ value when compared with Mastercool MSC52224-A ($P = .987$), ATD Tools 70001 Infrared Thermometer ($P = .985$), Mastercraft Digital Temperature Reader ($P = .972$), and Pro Point Infrared Thermometer ($P = .774$). The mean $\Delta T$ value for each thermometer is indicated in Table 2.

The interrater reliability was examined with the calculation of the intraclass correlation coefficient. for each thermometer. There was a high level of consistency and agreement between the 2 clinicians and the 5 thermometers (Table 3).

DISCUSSION
This clinical study was conducted to demonstrate that readily available infrared thermometers have an acceptable accuracy for clinical practice. The statistical analysis of periwound temperature data strongly supports the reliability between thermometers and...
operators of less expensive devices when compared with DermaTemp Exergen 1001. The strong interrater reliability that was obtained for all 5 thermometers confirms that the less expensive thermometers give similar temperature readings, regardless of the operator.

The study thermometers had valuable bedside tool features. All the thermometers had real-time scanning features. Thus, once the temperature acquisition started, the temperature would change as the thermometer was moved across a surface instead of pressing the button each time the operator moved to a new location. Arguably the most important feature in these thermometers is the “maximum temperature recorded” function. During the course of temperature acquisition, it is difficult for the clinician to remember the maximum temperature that was observed over and around the wound. This is because skin surface temperature is variable

Table 2.
THE MEAN TEMPERATURE GRADIENTS OF THE 5 DIFFERENT THERMOMETERS

<table>
<thead>
<tr>
<th>Thermometer</th>
<th>Mean “ΔT”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exergen DermaTemp 1001</td>
<td>2.38° F (SD, 3.54° F)</td>
</tr>
<tr>
<td>Mastercool MSC52224-A</td>
<td>2.68° F (SD, 4.06° F)*</td>
</tr>
<tr>
<td>ATD Tools 70001 Infrared Thermometer</td>
<td>2.67° F (SD, 3.93° F)*</td>
</tr>
<tr>
<td>Mastercraft Digital Temperature Reader</td>
<td>2.72° F (SD, 4.26° F)*</td>
</tr>
<tr>
<td>Pro Point Infrared Thermometer</td>
<td>3.91° F (SD, 3.80° F)*</td>
</tr>
</tbody>
</table>

*p = .987.
^P = .985.
^P = .972.
^P = .774.

Table 3.
INTERRATER RELIABILITY ASSESSED USING INTRACLASS CORRELATION COEFFICIENT (ICC)

<table>
<thead>
<tr>
<th>Thermometer</th>
<th>ICC*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exergen DermaTemp 1001</td>
<td>0.967 (0.92-0.987)</td>
</tr>
<tr>
<td>ATD Tools 70001 Infrared Thermometer</td>
<td>0.970 (0.925-0.988)</td>
</tr>
<tr>
<td>Mastercool MSC52224-A</td>
<td>0.968 (0.92-0.987)</td>
</tr>
<tr>
<td>Mastercraft Digital Temperature Reader</td>
<td>0.852 (0.884-0.981)</td>
</tr>
</tbody>
</table>

*95% Confidence interval values stated in parenthesis.
over a given surface area and may depend on vascular supply, inflammation, and infection. The authors’ previous work has already demonstrated that a temperature difference of greater than 3°F between a wound and mirror anatomical site, along with 2 or more other clinical signs, is highly suggestive of deep infection.5 Individual factor analysis for the clinical signs in the 7 STONEES criteria identified an elevated temperature to be 8 times more likely associated with deep and surrounding infection. All of the other 6 signs were 2 to 5 times more likely.5 In fact, the elevated temperature gradient is one of the most important indications of deep and surrounding infection. Although temperature elevation is suggestive of deep infection, it is also indicative of other causes of tissue damage. In the case of tissue damage, it is important to correct the cause and prevent further tissue damage. Systemic antibiotics should be ordered only when there is a deep and surrounding tissue infection.

An important feature of the infrared thermometers in this study is the distance-to-spot ratio. As the name suggests, this is a ratio between the distance to the object and the diameter of the object. For instance, if a device has a distance-to-spot ratio of 8:1, what this implies is that if the infrared thermometer was 8 inches away from the wound, the highest temperature within a 1-inch diameter of the wound surface would be recorded. The closer the thermometer is to the wound, the smaller the diameter of skin temperature differential that will be recorded. For a smaller wound, better temperature discrimination occurs in a smaller diameter if the thermometer is closer to the wound but not touching. The noncontact infrared thermometers tested in this study may help prevent the spread of infection. This is because of the higher distance-to-spot ratio, compared with the Exergen DermaTemp 1001, and the thermometers did not need to be too close to the wound, avoiding accidental contact and the risk of contaminating other wounds with subsequent examinations. In the authors’ experience, the Exergen DermaTemp 1001 examination will cause wound care providers to accidentally touch portions of the wound that could be a cause of future contamination to other patients. The thermometers should be swabbed with alcohol or other disinfectants between examinations.

Some of these thermometers also have a laser pointer. It is a common misconception that the laser pointer reads the temperature. It is most important to ensure that the aperture of the infrared thermometer is pointing at the wound and surrounding surface. Depending on the model of the infrared thermometer, temperature will be read above, below, or around the laser pointer. Another common misconception about infrared thermometers is that they provide information regarding internal temperature. This is absolutely false. Infrared thermometers are only skin surface temperature tools.

CONCLUSIONS

The results of this study demonstrate that less expensive, industrial-grade noncontact infrared thermometers possess reliable temperature readings that identify and quantify temperature gradients in the periwound skin. This study further demonstrates that infrared thermometers can add objectivity to the time-honored subjective method of clinical palpation for elevated skin temperature associated with deep and surrounding wound infection.

REFERENCES