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Benchmarking forensic rulers and photographic techniques

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ABSTRACT

Measuring various items (evidence) at the scene of an investigation, exposed to the elements, is an instrumental part of systematic forensic science. The key to these measurements often rest on rulers, and a knowledge of their limitations is vital to their appropriate application. The aim of this study was to test forensic ruler accuracy and photographic distortion under conditions that simulate common use to provide a foundational basis for baseline accuracy of their use. A series of ABFO rulers from 2 anonymous manufactures were tested against gold standards for accuracy at various temperatures (−14, 0, 25 and 40 °C). At the same time a series of rulers were photographed at different angulations to test reproducibility and angular distortion. At room temperature a variation of 0.28% in the dimensions of the rulers were found with larger distortions at colder temperatures. Photographs taken with the camera above the rulers suffered the least distortion (approximately 6–10°) and there was no difference over time, nor with ruler background colour. The results from this study show that further investigation is required into preventing angular distortion, and show the need for increased training to those who would be in a situation requiring them to document the scene of a crime.

1. Introduction

Measuring various items (evidence) at the scene of an investigation, exposed to the elements, is an instrumental part of systematic forensic science. The key to these measurements often rest on rules and a knowledge of their limitations is vital to their appropriate application. For example, the rulers used in forensic science need to be consistent and accurate in length. If these scales deviate by even a seemingly small percentage, this could lead to false evidence appearing in court cases and subsequent judgements and decisions being based on this.[2,6,9] Evidence is collected in all sorts of environments, including extreme conditions such as the Australian desert through to the Arctic. In all conditions, ranging from one extreme to the other, it is essential that forensic rulers maintain their integrity when used appropriately.[7] The average winter temperature approaches 1 °C, with lows of below 0 °C occurring in 16 states of the USA, reaching as low as −16.3 °C in Alaska. In Australia the average summer temperature is 28 °C and the Northern and Central parts of Australia frequently reach 35 °C, with extremes of up to 46 °C. A study conducted in Erie County, New York (mean minimum temperature −4.3 °C) found that 39% of all homicides (332 out of 527) occurred outdoors.[5] It is therefore important for the tools and equipment used, to be able to withstand these range of conditions, so that evidence may be photographed before it is removed to more ideal temperatures. A second underpinning assumption is that when photographing evidence, images are taken perpendicular to the evidence. Angular distortion means the image will not be a “true” representation of the shape and dimension of the evidence.[3] On occasions it is clear that hand held photographs are taken at scenes and therefore an exact perpendicular angle photograph is at times at risk of compromise. The aim of this study was to test forensic ruler accuracy and photographic distortion under conditions that simulate common use to provide a foundational basis for baseline accuracy of their use.

2. Methods and materials

2.1. Ruler accuracy

2.1.1. Sample set

A total of 11 metric and 7 imperial rulers were used in this study. Four metric rulers were manufactured by a single company (A) (2 yellow and black, 2 white and black) and the remaining by a

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different company B. All met the ABFO definitions for forensic rulers.[1]

2.1.2. Intra-operator calibration

Two of each of the metric and imperial rulers were measured 4 times over 8 days by a single researcher (JB). Each ruler was measured once, and a day break was taken before they were re-measured, to avoid any bias. Once completed, reliability as measured by mean and standard deviation variation between resampling, was determined.

2.1.3. Dental calliper benchmarking

The accuracy of a set of dental callipers was confirmed using a certified (Mitutoyo July 7th 2011) set of gauge blocks. The callipers were determined to be accurate and thus the 'gold standard' for this project.

2.1.4. Standard measurements

Each ruler was measured twice under standard conditions and an average obtained. For the purpose of this project standard temperature was deemed at 25 °C. The metric rulers were measured from the 80 mm mark towards the 0 mm mark, with each mm measurement taken from the difference between the previous 2 (for example 80.25–79 gave a mm length of 1.025). The imperial rulers were measured in the same way as the metric, starting at 2 inches and working down each 1/16th of an inch until 0. The two measurements were subtracted to give the length of 1/16th of an inch. The calliper was placed on one edge of the graduation mark and the same edge of the next for both the imperial and metric rulers. Total length and width measurements of the entire ruler were also taken.

2.1.5. 'Cold'; and 'hot' temperatures

Three other temperatures were used in this project. They were −14 °C, 0 °C and 40 °C. For the colder temperatures of −14 °C and 0 °C, a cooling plate from a tissue embedding station (Tissue Embedding System - TES 99 (Medite GmBH, Burgdorf, Germany)) was used. The temperature on the cooling pad varied from −15 °C to −14 °C and between −1 °C and 1 °C. To simulate 40 °C conditions a Breuer HK heating pad (Breuer GmBH, Ulm, Germany) was used. The temperature fluctuation was between 38 °C and 40 °C.

Under all conditions, after 5 min of temperature equilibration, the total length and width measurements of the rulers was measured with the calibrated callipers before detailed measuring commenced. The rulers were then measured in exactly the same way as under standard temperature conditions. Again, after a full 30 min at temperature, the total length and width of the ruler was documented. This was a further test of the rulers under sustained exposure to the temperatures.

2.1.6. Accuracy of reference circles

Photographs were taken of the rulers, at a perpendicular angle, under standard conditions. The camera (Nikon Coolpix L23, 10.1 MP) was mounted on a camera stand that had 2 spirit levels that ensured the camera stand was 1) on a flat surface, and 2) the angle in which the camera was over the ruler was perpendicular. Clearly, lens size (and shape) can influence outcome and therefore the same camera (at the same settings) was used for all samples. All areas of measurement were at the centre of each image taken. The reference circles were then analysed using Adobe Photoshop. The angle the rulers were on was corrected along the x-y axis by using the measurement tool in Photoshop and measuring across one side of the ruler and using the "arbitrary" image rotation tool to rotate the image (Fig. 1). Then the diameter of each circle was measured and a digital one was then created from these measurements, and

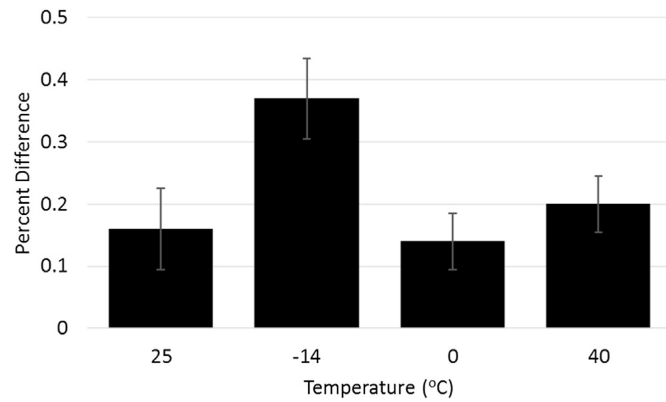

Fig. 1. The percentage difference (Mean and Standard deviation) in ruler length at different temperatures from the gold-standard length at room temperature.

compared to the reference circles. Thirdly the angles between each quadrant were then checked for 90°. Finally the radius of each quadrant was then measured to ensure it was the same on each side.

2.1.7. Statistical analysis

To determine if the changes in the rulers were significant, a one-way ANOVA was performed. If significance was found paired, two-tailed t-tests were performed between the mean length for each ruler between each temperature. The significance value was set at $p = 0.05$ and all statistics was completed with IBM SPSS Statistics 19 (IBM, New York, NY, USA).

2.2. Perpendicular photography

Photographs were taken on a surface that was 180°, 45°, 90°, 135° and −180° (ie taken from below with the camera face upwards). A simulated bite mark was drawn on a person's arm and photographs were taken of this to compare a flat and curved surface. Two rulers (with pre-determined, accurate reference circles) were used at room temperature. The rulers were different in their colour, one was yellow and black and the other white and black. A black and white background was alternated. Three photos were taken at each angle, with each ruler and each background (12 photos in total for each surface angle). Three photos were then taken with the yellow ruler, and 3 with the white ruler of the fake bite mark. This equated to 66 photos per day, over 5 days (330 photos in total). The daily protocol was: a photo was taken, operator walked away (minimum of 2.5 m), and returned to take another photo. Each surface angle was completed before moving on to the next. Photos were not submitted for analysis if they were out-of-focus and unable to be accurately analysed.

2.2.1. Analysis

Once all photos were taken, they were analysed for distortion using Adobe Photoshop, without any enhancements. The amount of distortion was calculated by solving for theta (the amount of non-parallelism in a photo). The protocol was based on the original developments of Bowers and Johansen.[3]

2.2.2. Statistical analysis

To determine if the photographs were taken at a consistent angle, a one-way ANOVA was performed on the mean theta values for each surface angle, and between each day. If differences were found, then the angle was considered inconsistent. Paired t-tests were performed between the theta values of different surface