Validation of the Artec Eva for Hand Anthropometric Data Collection

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As 3D technology rapidly improves, finely detailed areas of the human body, such as hands, are now able to be accurately scanned and measured. While previous studies have evaluated scanning of hands through surface maps, scan resolution, detail reproduction, and evaluated landmarking and hand scanning procedures (Griffin, Sokolowski, et al., 2018; Li et al., 2008; Redaelli, Gonizzi Barsanti, Fraschini, Biffi, & Colombo, 2018), the accuracy of measurements captured by 3D scanners has yet to be evaluated. This study aimed to evaluate the accuracy of measurements between specific hand landmarks when captured by the Artec Eva 3D scanner compared to traditional anthropometric measuring techniques.

Traditional anthropometry involves taking measurements of the human body by using tape measures and calipers (Gordon et al., 1989). 3D scanning for measurement extraction has been previously validated using a FastSCAN Cobra, where the distances between landmarks were measured in a customized program (Li, Chang, Dempsey, Ouyang, & Duan, 2008). A study by Griffin, Kim, et al. (2018) scanned hands using the Occipital Structure Sensor and analyzed hand measurement changes between dynamic postures. The Artec Eva's accuracy has been researched in multiple studies involving face and body scanning (Modabber et al., 2016; Redlarski, Krawczuk, & Palkowski, 2017; Shah & Luximon, 2017). Redlarski et al. (2017) used the Artec Eva to create full-body scans as "the scanner's maximum accuracy of 0.1 mm allows to produce high-quality 3D models" (p. 61). A study by Modabber et al. (2016) found that when measuring small objects attached to the face, the measurements were more accurately represented by the Artec Eva than the FaceScan3D scanner. However, none of these studies compared the measurement accuracy of the 3D scanners to traditional anthropometric measurements, highlighting the need to validate the accuracy of 3D scanners for hand measurement extraction.

This study followed a repeatable 3D scanning protocol for hands developed by Griffin, Sokolowski, et al. (2018) in order to minimize user error and to increase scanning efficiency. For traditional anthropometric measuring, the subjects' hands were measured in the splayed hand position as per ISO 7250-1:2017 (International Organization for Standardization 2017) (Fig. 2a). For 3D scanning with the Artec Eva, subjects' hands were also scanned in a splayed hand position developed through previous research by Griffin, Sokolowski et al. (2018) (Fig. 2b). The measurements extracted were hand length, hand breadth at metacarpals, hand thickness, and index finger circumference, proximal, based on definitions as per ISO 7250-1:2017 (International Organization for Standardization 2017).

Subjects were five men and five women; all were healthy, college-aged individuals with hands free from deformity or injury. Landmarks were applied to the subject's dominant hand (Fig. 1). Two tools were utilized for traditional anthropometric measuring. The Lafayette Instrument Evaluation Small Bone Caliper was used for hand length, hand breadth at metacarpals, and hand thickness. The Lafayette Instrument Evaluation Finger Circumference Gauge was used for index finger circumference, proximal (Fig 2a). The Artec Eva is a structured light, hand-held scanner that can be used for a variety of applications, including partial and full body scanning. It has a maximum accuracy of 0.01cm and produces high resolution and highly detailed models (Shah & Luximon, 2017).

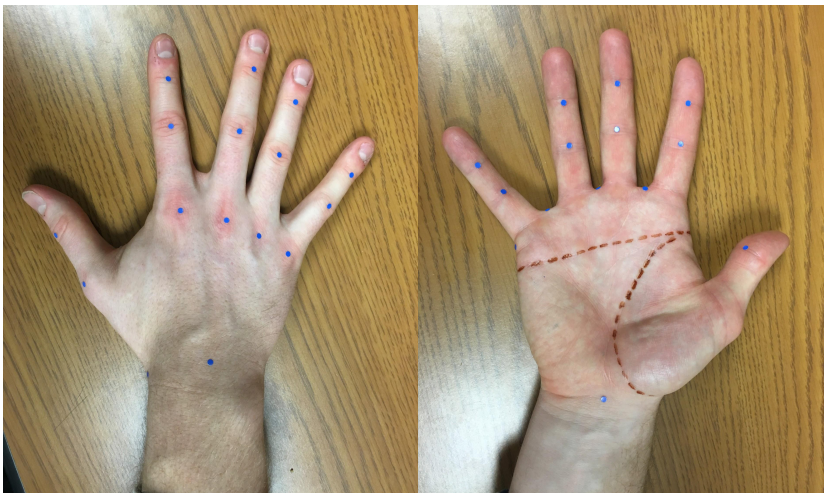

Fig. 1. Landmark placement on hand

3D scans from the Artec Eva were imported into Anthroscan©, scaled, and measurements extracted based on landmarks (Fig 2b). For both techniques, each measurement was extracted three times by the same researcher to calculate repeatability error. Results from the paired *t*-tests showed no statistically significant difference ($p > 0.05$) in measurement for both hand breadth and index finger circumference, proximal for the Artec Eva when compared to traditional anthropometric measuring. However, hand length and hand thickness did show a statistically significant difference ($p < 0.05$) between the Artec Eva and traditional anthropometric measuring.

The discrepancies in measurements may be due to issues found during scanning with the Artec Eva. The scanner requires a trained operator with experience in order to effectively scan. Due to the scanner being tethered to a laptop, it can be challenging to manage while scanning. A lack of vertical support for the subjects' arms caused movement by subjects, which distorted the 3D models. Issues with tools were also noted during traditional anthropometric measuring, especially regarding hand length and the small bone caliper. Results indicate that further analysis is needed to confirm the Artec Eva is a viable tool for measurement extraction.

Despite these issues, the Artec Eva produced high-quality scans with good landmark and detail visibility. This provides clear details that are needed to design better tools and products for hands. It also improves the ability to extract dimensions from the 3D scans. As per Griffin, Kim et al. (2018), there is a

"need for a large 3D anthropometric survey of dynamic hand positions and the formation of a database" (p. 47). In order to create this database, it is important to understand the limitations and capabilities of not only 3D scanning but also traditional anthropometric measuring techniques. Up to this point, neither method is perfect. As 3D technology improves, the ability to collect better 3D scans and extract more accurate measurements will increase. Results from this study inform us of some of these limitations and capabilities of technology for extracting measurements from 3D scans. This type of research needs to be continued to better understand new technology and equipment in order to gain more knowledge of the human hand.

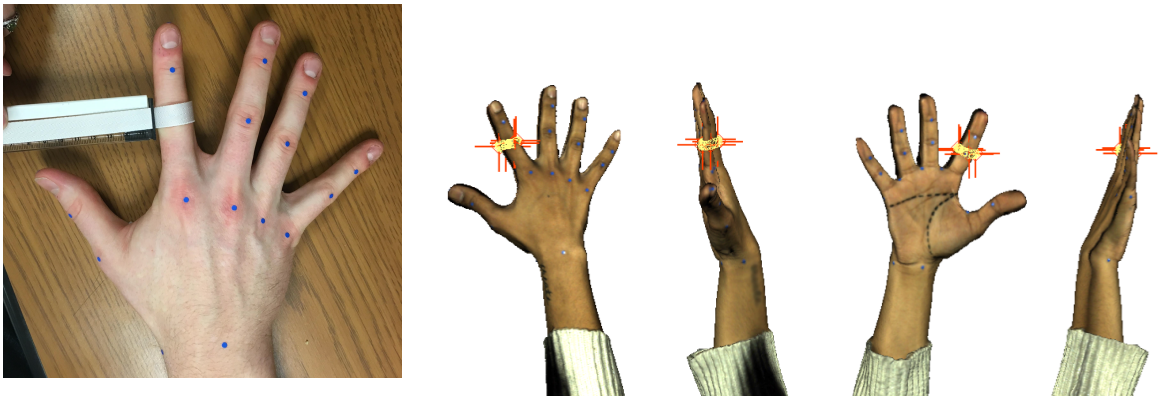

Fig. 2. Index finger circumference, proximal for traditional anthropometric measurement (a); Anthroscan© measurement extraction (b).

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