Accuracies of Artec® Spider®, EinScan® Pro 2X, NextEngine®, and Qlone® Photogrammetry for 3D Bone Data Analysis in Forensic Anthropology

Thomas Beresford, BSc (Hons)[1]; Tiina Manne, PhD[2]; Kelvin Henderson, BBiomedSc[2]; Chris Glen, BSc (Hons)[1]; Carl N. Stephan, PhD[1]

[1] Laboratory for Human Craniofacial and Skeletal Identification, School of Biomedical Sciences, The University of Queensland, Australia; [2] School of Social Sciences, The University of Queensland, Australia.

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

Introduction

In forensic anthropology, 3D optical surface scans are increasingly being used to assist skeletal assessments (Fig. 1) [1-3]. These 3D scanners are commonly used out-of-the-box on the presumption that manufacturer stipulated accuracies apply. However, manufacturers often do not test to VDI/VDE Part 3 standards [4], tests are not conducted using human bone, tests are not conducted using the settings popularly employed to acquire human bone, and some bones are larger than the ideal sizes for which the scanners are designed per their measuring volumes.

To investigate these matters further, this study reports scan errors for eight human bones scanned on four popular 3D capture devices as compared to a metrology-grade Solutionix reference scanner (the latter of which comes complete with an error test certificate meeting VDI/VDE standards).

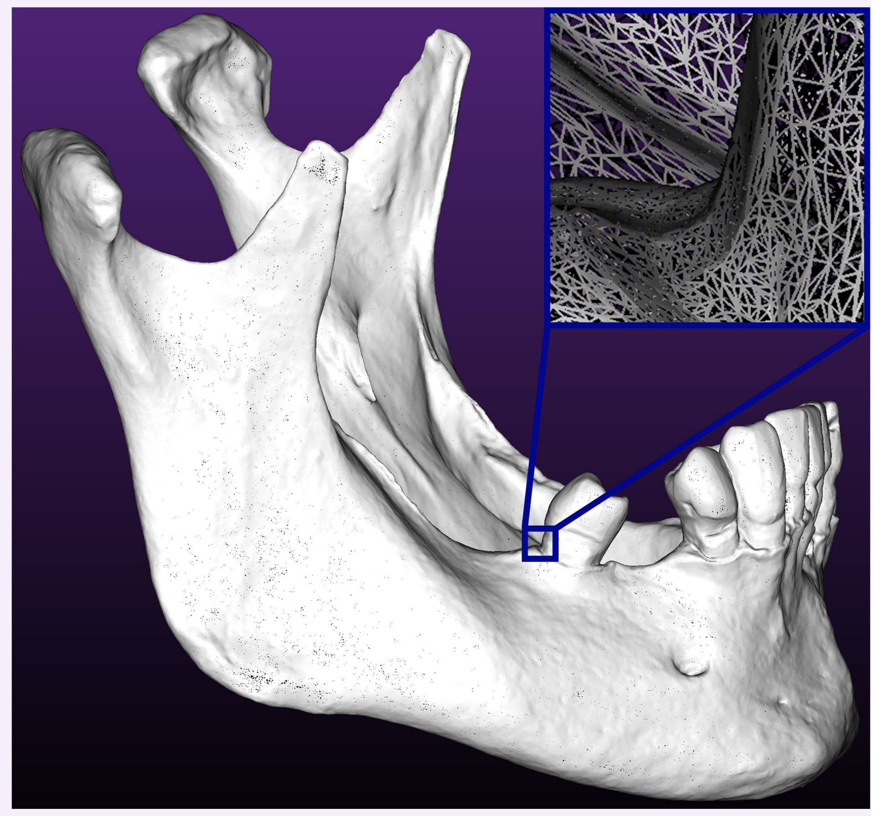

Figure 1. A 3D surface mesh reconstruction of a human mandible taken using a 3D scanner. Inset shows triangular mesh of surface at high magnification.

Methods

Eight whole bones were scanned 10 times with each of the four test scanners and once with the reference scanner. The bones were a C4 vertebra, clavicle, femur, mandible, second metacarpal, radius, scapula and talus. The three tests scanners included an Artec® Spider, an EinScan® Pro 2X, NextEngine® Ultra HD, and one photogrammetry method (iPhone® via Qlone®) (Fig. 2). The reference scanner was a metrology-grade Solutionix® C500 (Fig. 2).

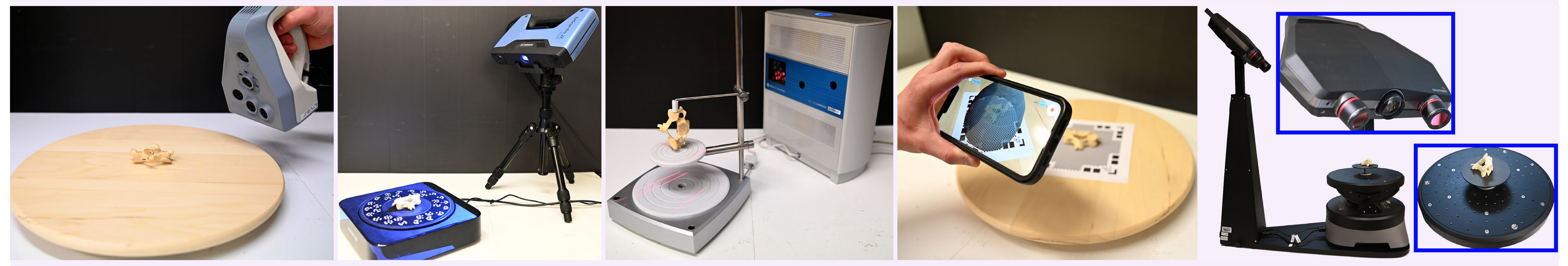

Figure 2. 3D scanners used. From left to right: Artec® Spider® ($17.5K), EinScan® Pro 2X ($6K), NextEngine® Ultra HD ($3K), Qlone® photogrammetry ($0), Solutionix® C500 ($38K).

For each 3D scanner, the most user friendly software settings were used to enable fast scan acquisition, e.g., the Autopilot feature in Artec® Studio® 12 for the Artec® Spider®.

CloudCompare® software was used to align test scans to their reference scan using an iterative closest point algorithm, before pairwise mesh-to-mesh distances were computed (n=320).

Two statistics were used to measure the error (mean absolute error [MAE] and signed error) and these were plotted using 3D heat maps.

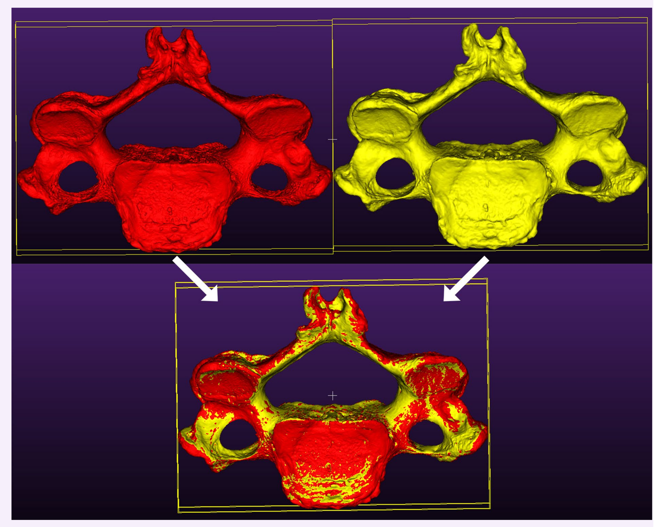

Figure 3. Iterative closest point alignment of 3D scans.

Results

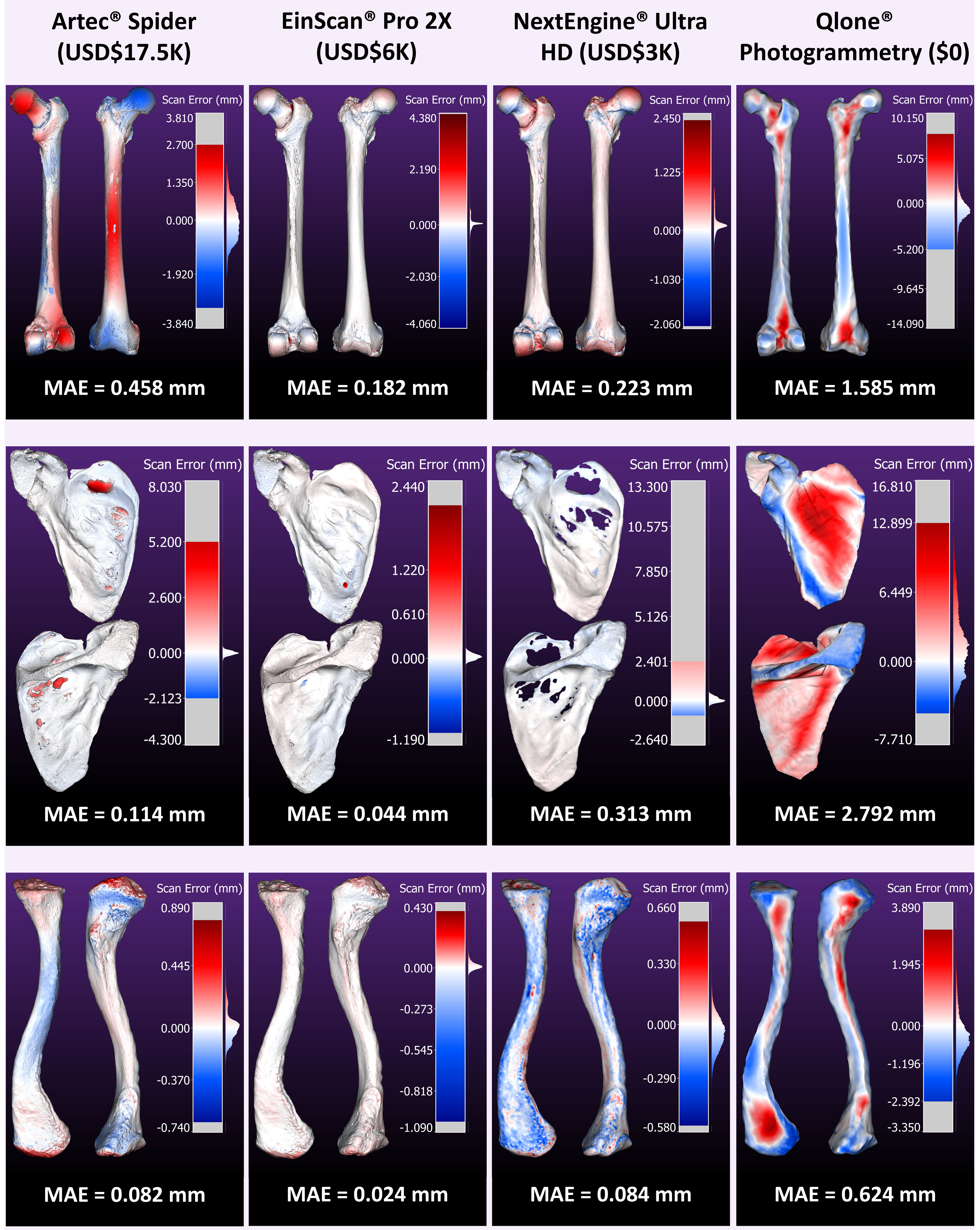

Figure 4. Examples of scan error heat maps for three examples (femur, scapula, clavicle) of the eight selected bones. Error is relative to the reference scanner (mm). Heat maps are accompanied by the grand MAE value (mm) for that scanner.

Discussion

Across all 3D test scanners, none reproduced their manufacturer-stated error values across all eight bones. Large bones that possessed parts that fell outside the measuring volume tended to possess larger errors than smaller bones that fit neatly within the measuring volume. For optical scanners (Artec®, EinScan®, NextEngine®), manufacturer-stated error values were reproduced for small bones that fit within the measuring volume of the scanner.

For the Artec® Spider® and concerning its results of substantial error for large long bone scans on Autopilot, the Autopilot feature in Artec Studio 12 is not recommended for precision scanning. Preliminary observations suggest that using manual mode instead of Autopilot can substantially reduce the errors of the Artec® Spider® scans.

Qlone® was not observed to provide sufficient accuracies for 3D bone quantification in the forensic anthropology context.

Conclusion

3D scanners should be performance checked prior to being used for scientific analysis in forensic anthropology because manufacturer-stated accuracies do not adequately describe the errors arising from the instrument when scanning human skeletal elements. This is likely to have knock on effects for biological profile determination, osteometric sorting and human identification methods, where additional errors introduced by 3D scanning are likely to reduce method performance when 3D scans are used.

Ideally, performance testing of scanners should be undertaken using real bone as undertaken in this study in conjunction with a higher precision reference scanner, whose accuracy has been confirmed by VDI/VDE testing.

VDI/VDE 2634 Part 3 reverification testing of 3D scanners [4] using calibrated ceramic ball bars provides an additional error test capability that holds advantages when used in combination with bone tests, especially for those instruments that do not ship with a VDI/VDE-compliant calibration certificate.

References

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This study forms a subcomponent of a larger body of work that uses additional 3D scanners and photogrammetry methods conducted in conjunction with Dr John Byrd and Dr Jodi Caple, DPAA.