H20 Virtual Skull Anatomy: Three-Dimensional Computer Modeling and Measurement of Human Cranial Anatomy

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This presentation will demonstrate the value of computed virtual models of anatomical structures and three-dimensional (3D) rapid proto- typing as an accurate tool in the study of human cranial anatomy. This presentation will compare three-dimensional data sets and computer modeling to traditional caliper methodologies, as well as to current morphometric software packages.

This presentation will impact the forensic community by serving to increase scientific knowledge of new technologies and methods available to the forensic community that may ultimately increase the accuracy of human identification. Three-dimensional data sets from CT and MR images, regularly used in the medical community, are becoming of increasing value to other fields such as biological anthropology and the forensic sciences because of their ability to expand the accessibility of anatomical material beyond physical contact.

Using three-dimensional (3D) imaging technology, researchers are able to create virtual computed models of anatomical structures for a wide range of educational and research activities. The goal of this study was to compare the accuracy of measurements made using computed 3-D imaging tech- nology to data obtained by traditional caliper measurement methodologies and current morphometric software packages, such as *morphologika* 2 © (O'Higgins and Jones, 2006).

This pilot study began by utilizing randomly selected specimens such as intact human cadaver heads and dry human skulls for use in CT and MR scans, virtual reconstruction, and prototyping.

Virtual skull models were computed from the volumetric CT and MR image data using Mimics © version 10 (Materialise). Twenty five anthro- pometric measurements were selected from Buikstra and Ubelaker's[1] index of standard cranial landmarks based on their effectiveness in establishing a biological profile in skeletal analysis. Measurements of the virtual computed skull models were made using *3ds Max* © (Autodesk, version 9).

A 3D rapid prototype was then generated, using a Zcorp 3D ZPrinter© 310 Plus. In the 3-D printing, layer upon layer of fine ZP 102 Powder was pressed until it formed a prototype of the cadaver skull. After printing, Z-Bond TM 101 Medium Strength Cyanoacrylate Binder glue was used to fix the specimen for handling. The prototype was then measured using the same indices as the virtual skull. The printed model contains all external and internal anatomy of the actual skull including the frontal sinuses. After 3D modeling and prototyping the specimen, the cadaver head was processed and the skull recovered and cleaned. Measurements were then taken from the actual skull. Comparisons were subsequently made with the models from the CT images and the prototype.

In the study, the actual measurements of the virtual skulls were consistent with those taken from the actual skulls even considering inter- observer error. Statistical analysis of the measurements data comparing all of the samples (actual, virtual and prototype), confirmed the accuracy of the computer modeling and measurement technologies. Additionally, it was found the prototypes to be a valuable reproduction of the original skulls, even taking into consideration artifacts from the printing process. Future steps will be taken to explore how to reduce inter-observer error further.

By using methodologies developed and validated in this study, the researchers are now confident that anatomically accurate virtual and/or proto- typic anatomical models can be produced using state of the art medical imaging and computer technology for use in a wide range of anatomical structures for use in medicine, biological anthropology and the forensic sciences.

This study demonstrates that 3-D datasets are a useful and accurate tool to the study of human anatomy for both clinical and forensic purposes. Virtual anatomy will ultimately provide the opportunity to reevaluate current methods of analysis and create new ones which will, in turn, increase the accuracy of results and expand the accessibility to anatomical specimens beyond actual contact. The ongoing study includes the validation of this method to establish a biological profile (age at death, sex, ancestry and body type) based on the accuracy of morphological features of human skulls, as well as a comparison of virtual facial approximation methods.

[1] Buikstra JE, Ubelaker DH (eds.) (1994) *Standards for Data Collection from Human Skeletal Remains.* Arkansas Archaeological Survey Research Series No. 44.

3-D Imaging, Computer Modeling, Human Cranial Anatomy

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