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Comparison of two scanning modalities for ancestry estimation using the mid-facial skeleton.

Content

Abstract
Estimating ancestry from skeletal remains is a key component in formulating the biological profile. The mid-facial region of the cranium is one of the most discriminatory skeletal elements in ancestry estimation. In heterogeneous countries like South Africa, innovative techniques need to be established to quantify variation attributable to ancestry differences. The current study explored the efficiency of three-dimensional (3D) surface scanning in evaluating ancestry-related shape variation compared to Micro Computed Tomography (Micro-XCT) scanners using geometric morphometric methods (GMM). Additionally, this study tested the reproducibility of the craniometric landmark placement and the geometric discrepancy between the two modalities.

Forty-one crania of Black and White South Africans were assessed using forty-one mid-facial landmarks. Two sets of data were collected from each cranium, namely Micro-XCT scans and 3D surface scans.
On both scans of each cranium, forty-one landmarks were manually placed using the Avizo 8.0 software. First, shape analyses were conducted using GMM to assess and compare ancestry-related shape variations obtained from the two scanning modalities. Secondly, parametric (ANOVA) and non-parametric (permutation testing) tests were employed to assess the influence of ancestry on the mid-facial shape variations. A repeatability test was conducted to assess landmark placement reproducibility on both scanning modalities. A General Procrustes Analysis was conducted to obtain orientation-variant shape coordinates. A principal component analysis was also conducted to create independent transformed variables as (principal component scores) to assess ancestry-related shape variations between both scanning modalities. Geometric discrepancies were assessed through the alignment and superimposition of the 3D reconstructions from both scanning modalities. Shape variations between the two scanning modalities were noted to be similar, with statistically significant p-values ($p < 0.001$). Discriminant function analysis (DFA) was used for ancestry classification purposes. A 100% classification accuracy was obtained for Black individuals, using Micro-XCT and 3D surface scans. White individuals were correctly classified with 94% accuracy from Micro-XCT scans and 88% from 3D surface scans. Repeatability testing for both intra- and inter-observer error using Micro-XCT scans showed the left and right Orbitale had the highest and Rhinion and Nasomaxillare the lowest dispersion values, respectively. On the 3D surface scans, the left and right Submaxillare curvatures had high dispersion values, with the Zygomatico Superior having the lowest values. The PCA data revealed similar ancestry-related shape variations were observed for both modalities, with analogous overlap between Black and White South Africans. Geometric discrepancies visualization was performed to calculate the surface distances obtained between aligned 3D reconstructions of both 3D scanning modalities using the same specimen. Discrepancies were observed in the area of the Submaxillare curvatures. The visualization of the geometric discrepancies was consistent with the statistical analysis results.
This study suggests that 3D surface scanners can be utilized for ancestry estimation using GMM. The introduction of 3D surface scanners may reduce measurement error and may validate ancestry estimation results obtained through the traditional osteometric method can be in a forensic setting. However, more extensive research is required with larger sample size, and more population groups to support the findings from this study.

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