Examining Population Affinity using Occlusal Polygons of the Molars

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Introduction

Dental morphology has long been utilized in anthropology as a means to examine population affinity. Occlusal polygons, a pseudo-geometric morphometric technique developed to measure teeth for the purpose of investigating population affinity, utilizes the length, angles between cusp tips, and area of the molar crowns by using each cusp tip as a vertex (Morris 1986).

The purpose of this research was to explore the variation present in the relative cusp location between three ancestral groups using occlusal polygons and geometric morphometric analyses (GMA).

Samples

African (n=52)
- crania from the Hamann-Todd Collection housed at the Cleveland Museum of Natural History

Asian (n=28)
- dental casts from the University of Alaska, Fairbanks Anthropology Department

European (n=105)
- dental casts from the University of Alaska, Fairbanks Anthropology Department

Data Collection

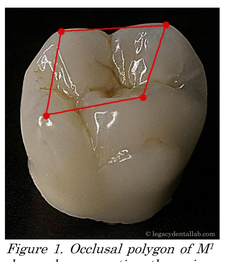

Figure 1. Occlusal polygon of M^1 drawn by connecting the apices of each cusp.

Coordinate data were collected from the primary cusp tips of the first and second maxillary and mandibular molars from 185 individuals using a Microscribe G2 digitizer and a modified version of the 3Skull software program (Fig 1).

Statistical Methods

Geometric Morphometric Analyses in MorphoJ
- z coordinate was removed to negate the effects of tooth wear
- raw coordinate data subjected to a Generalized Procrustes Analysis and Procrustes Coordinates (PC) generated
- PC analyzed using Canonical Variates Analysis (CVA)
- Inter-landmark distances (ILDs) calculated from the coordinate data

Discriminant Function Analysis (DFA) in SPSS
- using PC for classification based on shape
- using ILDS for classification based predominantly on size, but also including shape
- DFA utilized Forward Wilks' stepwise selection

Results

CVA:
- M^1: CV1 accounting for 70.1% of the variation. Major shape changes in all 4 cusps (Fig 2a) with no clear distinction between groups, but greater overlap of the Asian and European groups (Fig 2b).
- M^2: CV1 accounting for 78.6% of the variation. Major shape changes in all 4 cusps (Fig 3a) with slight separation of the Asian group from the African and European groups along CV2 (Fig 3b).
- M_1: CV1 accounting for 71.7% of the variation. Greater shape changes in the lingual cusps (Fig 4a) with separation of the African and European groups along CV1 (Fig 4b).
- M_2: CV1 accounting for 95.3% of the variation. Greater shape changes in the distal cusps (Fig 5a) with separation of the African and European groups along CV1 (Fig 5b).

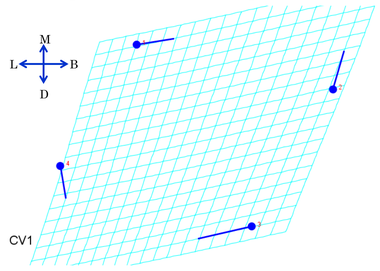

Figure 2a. Visualization of shape changes using CV1 in M^1. (1) Protocone (2) Paracone (3) Metacone (4) Hypocone.

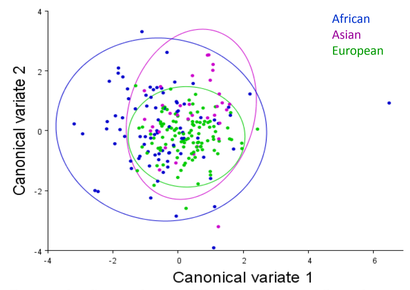

Figure 2b. Scatterplot of CV1 on CV2 for M^1 with 95% confidence ellipses for each group.

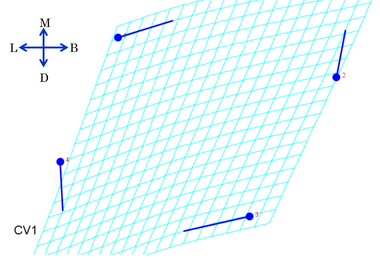

Figure 3a. Visualization of shape changes using CV1 in M^2. (1) Protocone (2) Paracone (3) Metacone (4) Hypocone.

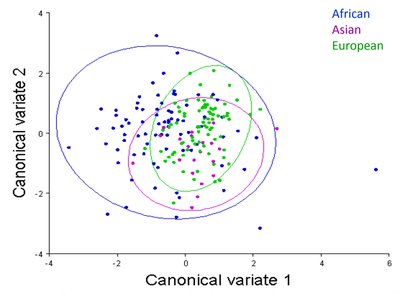

Figure 3b. Scatterplot of CV1 on CV2 for M^2 with 95% confidence ellipses for each group.

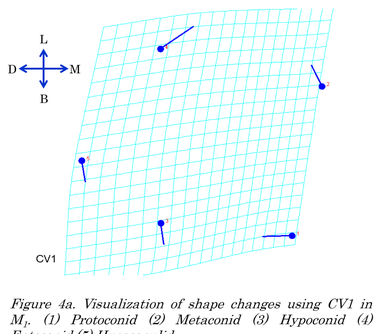

Figure 4a. Visualization of shape changes using CV1 in M_1. (1) Protoconid (2) Metaconid (3) Hypoconid (4) Entoconid (5) Hypoconulid.

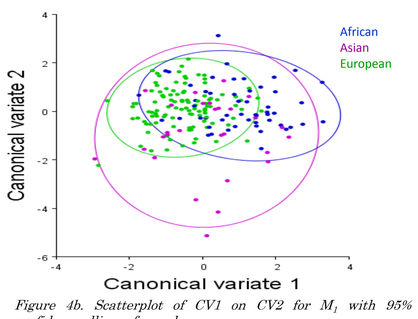

Figure 4b. Scatterplot of CV1 on CV2 for M_1 with 95% confidence ellipses for each group.

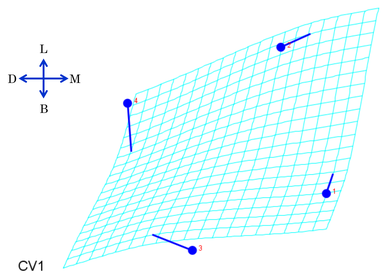

Figure 5a. Visualization of shape changes using CV1 in M_2. (1) Protoconid (2) Metaconid (3) Hypoconid (4) Entoconid.

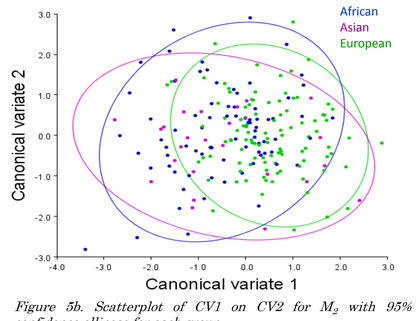

Figure 5b. Scatterplot of CV1 on CV2 for M_2 with 95% confidence ellipses for each group.

DFA: Using a three-way analysis for ancestry, correct classification using PC averaged 84.6%. Correct classification using PC was highest in individuals of African descent (97.2%), while correct classifications for individuals of European descent averaged 78.9% and for individuals of Asian descent averaged 72.5% (Tables 1-4). Percent correct classification by individual tooth for ancestral group averaged 51.4% using ILDs (Tables 5-8). Correct classification using ILDs was highest in individuals of European descent 59.0% (Tables 5-8).

Table 1. Cross validated classification accuracy (%) for M^1 using PC. 87.2% of cross-validated grouped cases correctly classified.

M^1	African	Asian	European
African	**96.4**	2.4	1.2
Asian	0	**70.6**	29.4
European	0	14.7	**85.3**

Table 2. Cross validated classification accuracy (%) for M_1 using PC. 79.5% of cross-validated grouped cases correctly classified.

M_1	African	Asian	European
African	**96.2**	0	3.8
Asian	0	**67.9**	32.1
European	0	25.7	**74.3**

Table 3. Cross validated classification accuracy (%) for M^2 using PC. 86.2% of cross-validated grouped cases correctly classified.

M^2	African	Asian	European
African	**98.7**	0	1.3
Asian	0	**66.7**	33.3
European	0	20.7	**79.3**

Table 4 Cross validated classification accuracy (%) for M_2 using PC. 85.4% of cross-validated grouped cases correctly classified.

M_2	African	Asian	European
African	**97.4**	0	2.6
Asian	0	**84.6**	15.4
European	0	23.5	**76.5**

Table 5. Cross validated classification accuracy (%) for M^1 using ILDs. 50.7% of cross-validated grouped cases correctly classified.

M^1	African	Asian	European
African	**46.4**	15.5	38.1
Asian	11.8	**58.8**	29.4
European	32.1	16.5	**51.4**

Table 6. Cross validated classification accuracy (%) for M_1 using ILDs. 52.4% of cross-validated grouped cases correctly classified.

M_1	African	Asian	European
African	**53.8**	23.1	23.1
Asian	25.0	**50.0**	25.0
European	35.2	12.4	**52.4**

Table 7. Cross validated classification accuracy (%) for M^2 using ILDs. 51.4% of cross-validated grouped cases correctly classified.

M^2	African	Asian	European
African	**37.2**	20.5	42.3
Asian	28.6	**57.1**	14.3
European	19.5	17.1	**63.4**

Table 8 Cross validated classification accuracy (%) for M_2 using ILDs. 51.2% of cross-validated grouped cases correctly classified.

M_2	African	Asian	European
African	**36.7**	31.6	31.6
Asian	42.3	**26.9**	30.8
European	8.8	22.5	**68.6**

Discussion and Conclusions

CVA: Visualization indicates relatively equal shape changes in all cusps of the upper molars that are significant, while the mesial cusps of the lower molars exhibited less shape changes than the distal cusps using CV1.

Classification using PC: When individuals in the Asian group misclassified, they did so as European. Similarly, Europeans, when misclassified, always grouped with the Asian sample. Of the three groups, individuals in the African sample overwhelmingly classified more accurately than the Asian and European samples. In all teeth with the exception of the first maxillary molar, African individuals misclassified as European. Based on the closer geographic proximity of Africa to Europe than to Asia, the misclassification into the European group is not surprising. These results suggest that as the group with the oldest evolutionary age, the African dentition is more stable than the other two populations, who diverged later and share a more similar dental shape pattern with each other than with the African group.

Classification using ILDs: Interestingly, the highest group classification accuracies using ILDs varied by tooth, with no ancestral group classifying best in all teeth as was found using PC. Furthermore, classification accuracies using the size and shape (ILDs) were much lower than those using shape alone (PC).

In summary, the utility of modern geometric morphometric analyses using the first and second molars, both maxillary and mandibular, has been demonstrated and can significantly discriminate between modern population groups.

Acknowledgements

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