Geometric Analysis and Visualization of Maxillofacial Anthropometry

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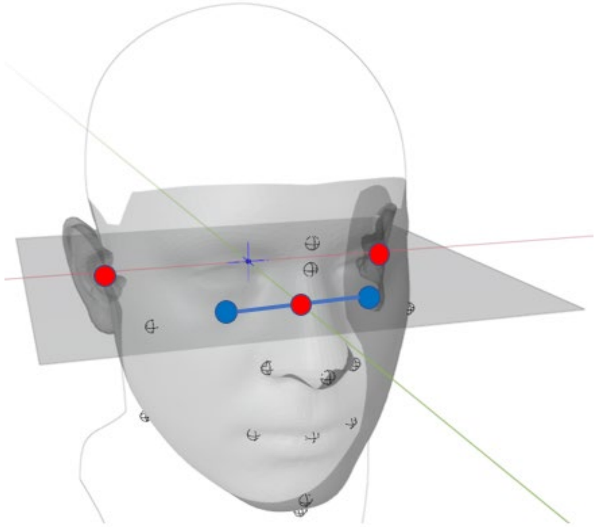
Introduction

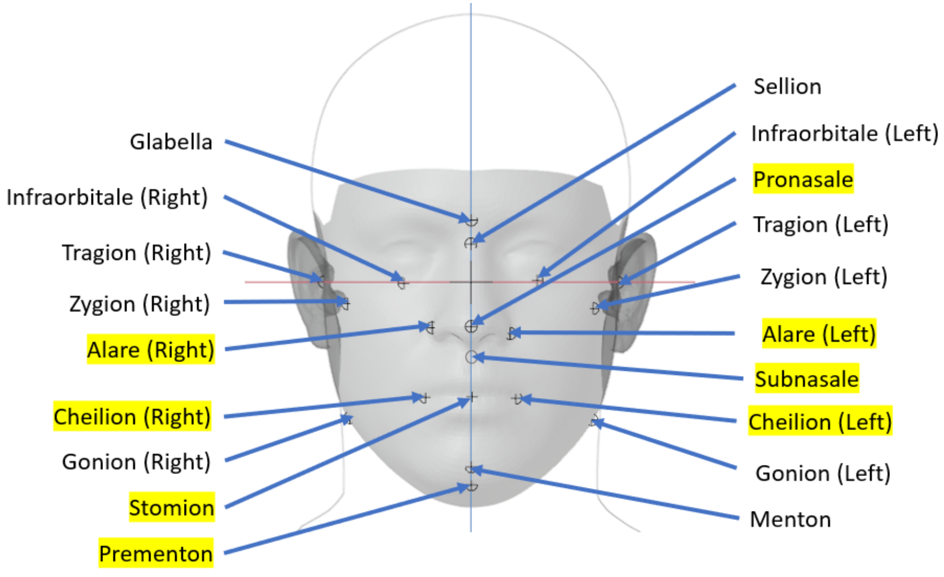
- NASA Johnson Space Center, Anthropometry and Biomechanics Facility
- United States Army, Applied Ergonomics Group
  - Anthropometric Surveys (ANSUR)
- Scope of work
  - Facial anthropometry database analysis and visualization
- Background
  - Design of head borne equipment
    - Space: In-suit communications equipment and PPE
    - Military: Communications equipment and maxillofacial armor

ANSUR I & II Facial Landmark Survey

- ANSUR I
  - 1,774 Males, 2,179 Females, Total 3,953
  - 2,346 White, 1,403 Black, 161 Hispanic, 77 Asian
- ANSUR II
  - 3,582 Males, 1,373 Females, Total 4,955
  - 3,405 White, 951 Black, 614 Hispanic, 240 Asian
- Both data sets were aligned to a Frankfort head plane coordinate system.
- Missing and outlier data points were predicted using a linear regression model.



Frankfort head plane aligned head



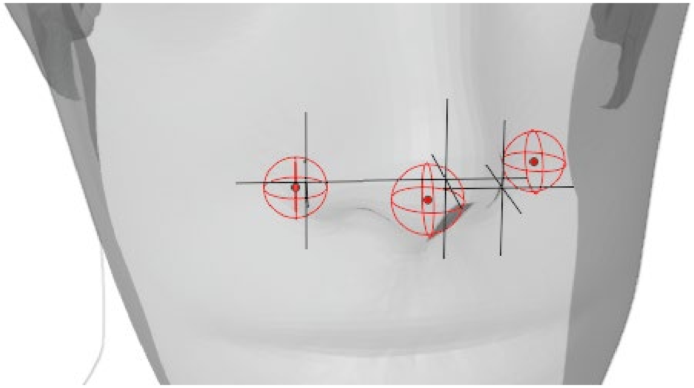
ANSUR Landmarks, highlighted landmarks only measured for ANSUR I

Unmeasured Landmarks for ANSUR II

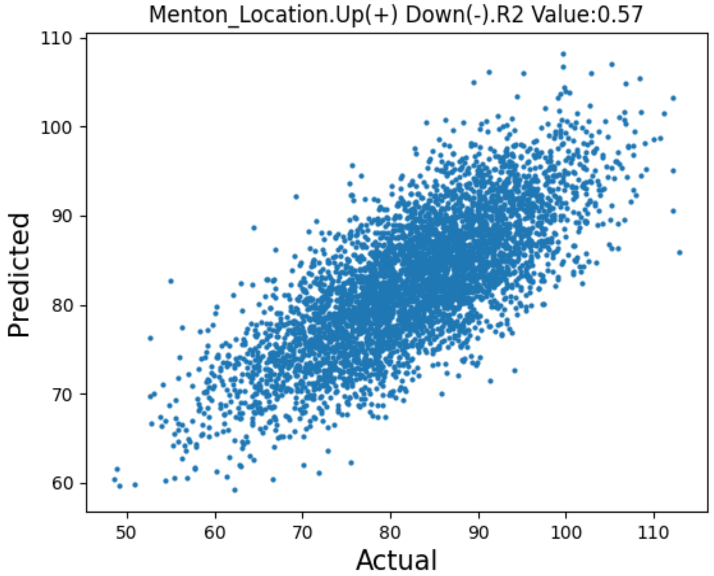
- The Alare (left and right), Cheilion (left and right), Prementon, Subnasale, Pronasale, and stomion landmarks were only recorded for ANSUR I.
- A prediction model was made for the coordinate of each missing landmark, where the landmarks present in both datasets were used to predict the missing landmark coordinate.
- These models were used to predict the unmeasured ANSUR I landmarks for the ANSUR II survey subjects.
- A similar technique was used to predict the location of missing and outlier datapoints in the ANSUR I and ANSUR II databases.

Landmark Location Estimation Cross Validation

- The missing landmark prediction model was cross validated for accuracy.
- Using Leave One Out Cross Validation (LOOCV), landmark locations of complete subject datasets were predicted and verified against known landmark locations.
- The resultant plot can be used to understand how well the model can predict the landmark location in question.
- R^2 scores were used to evaluate the quality of a regression model.
- The R^2 scores from linear regression shows:
    - The R2 was as high as 0.89 and low as 0.27
    - Several landmark shows "good" R^2 scores (over 0.6), thus regression models can effectively predict the missing landmark positions
    - Some landmarks show low R^2 scores, but possibly due to shape asymmetry or probably measurement inconsistency (e.g., menton x-coordinate)

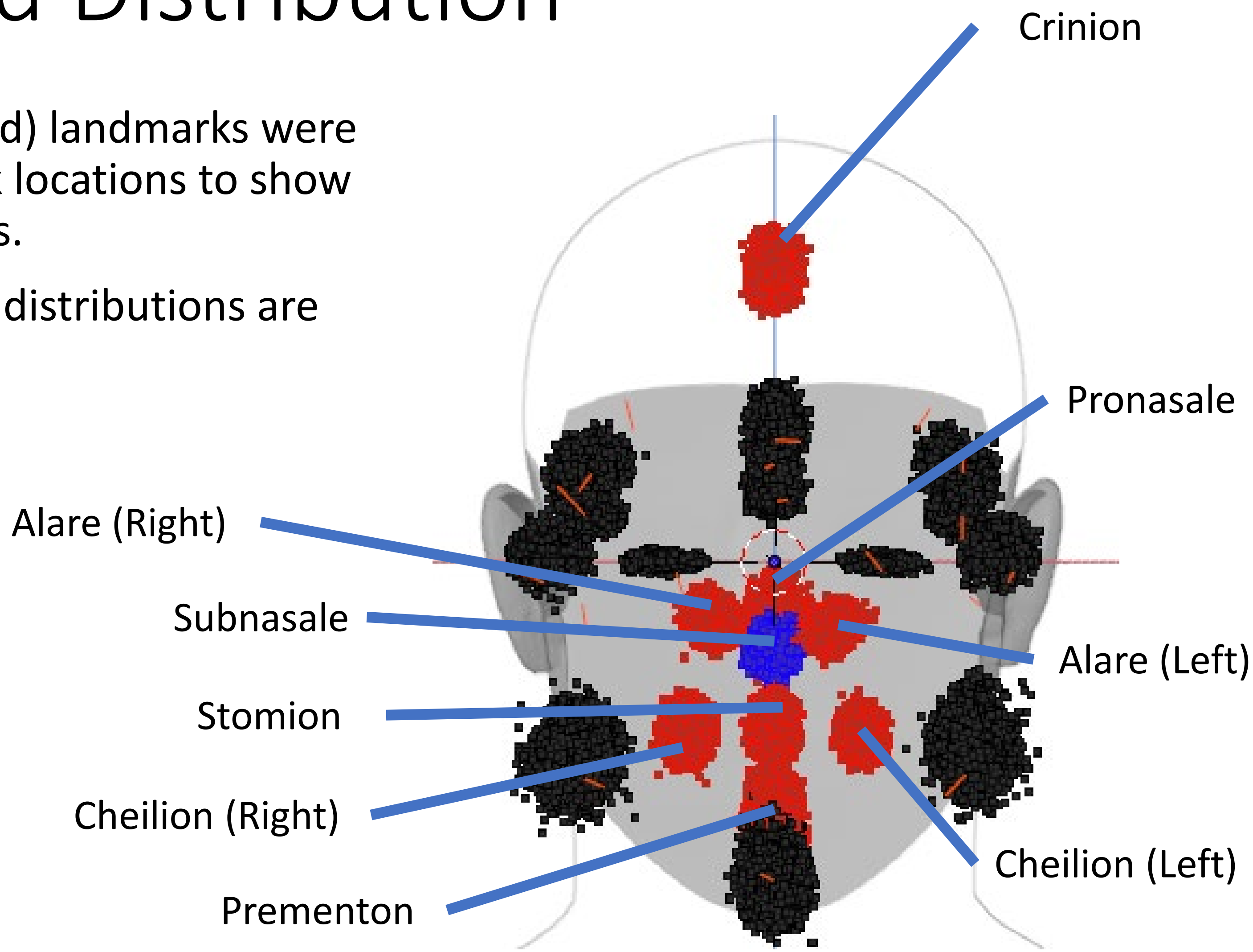


Example of predicted landmarks,
black crosses: actual data, red spheres: predicted data



ANSUR II Point Cloud Distribution

- The location of all predicted (non-measured) landmarks were plotted along with the measured landmark locations to show the relative locations of the new landmarks.
- The location of the new landmark location distributions are correct relative to non-predicted data.



Black Point Clouds: Distribution of measured ANSUR II Landmarks
Orange Point Clouds: Distribution of Predicted unmeasured ANSUR II Landmarks

Linear Regression Model

- A regression model was made to investigate the differences in face shape by gender and ethnicity from the average white male face.
- The model has this structure…
  - Landmark Location Value ~ Gender Effect + Ethnicity Effect + Average White Male Value

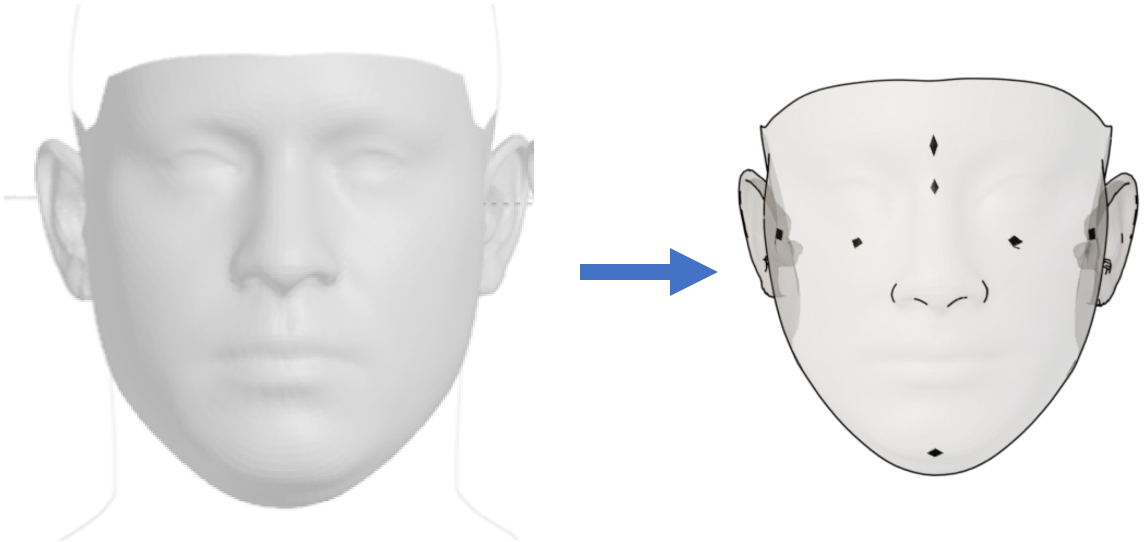
Linear Regression Model for Tragion and Gonion Landmarks

		Coeffecients						Intercept
Landmark	**XYZ**	**Male**	**Female**	**White**	**Black**	**Hispanic**	**Asian**	**Intercept**
Tragion_Location_Left	X	0.0	4.7	0.0	-0.4	-1.1	-2.1	-74.4
Tragion_Location_Right	X	0.0	-4.7	0.0	0.4	1.1	2.1	74.4
Gonion_Location_Left	X	0.0	5.4	0.0	-1.5	-1.6	-1.6	-63.8
Gonion_Location_Left	Y	0.0	13.8	0.0	2.8	0.8	-0.9	14.9
Gonion_Location_Left	Z	0.0	9.8	0.0	-0.8	-0.3	-0.8	-65.1
Gonion_Location_Right	X	0.0	-4.9	0.0	1.6	1.9	2.2	64.2
Gonion_Location_Right	Y	0.0	12.0	0.0	2.2	0.2	-2.1	17.5
Gonion_Location_Right	Z	0.0	8.6	0.0	-0.5	0.2	-0.4	-60.5

X: +right-left, Y: +fore-aft, Z: +up-down, unit: mm

Morphing Head Visualization Tool

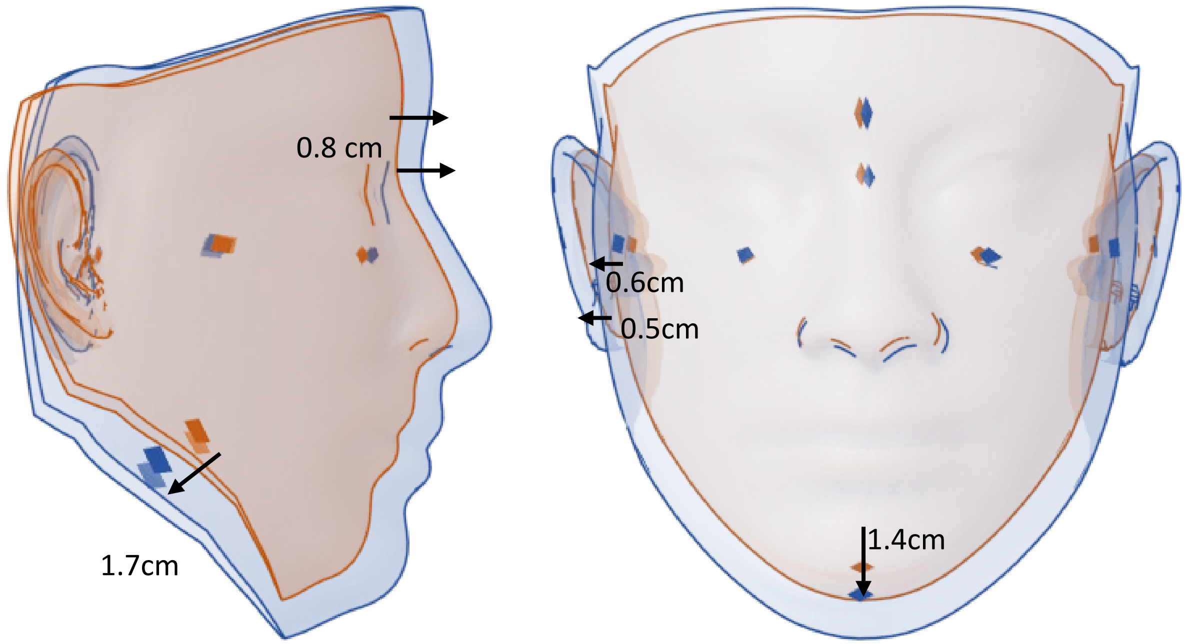
- A face shape visualization tool was created that uses a radial basis function to deform a template face shape to reflect a given face shape.
- The model used the landmarks as control points to aid in deforming the face shape.
- The visualization tool was used with the linear regression model to visualize the effect of gender and ethnicity on face shape.



Deformed Head Demonstration;
left: template face, right: average female face

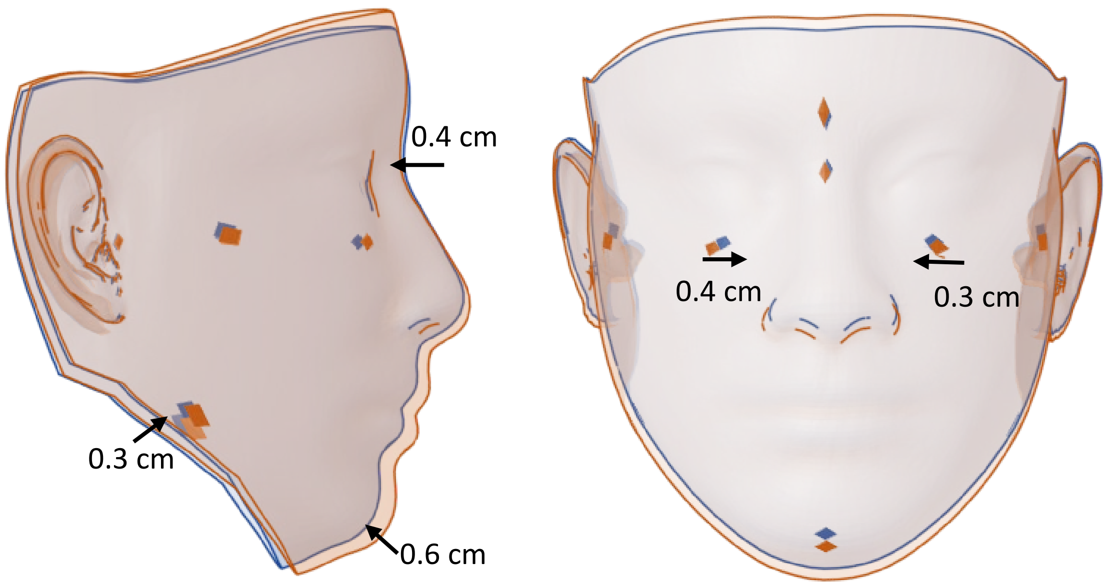
Landmark and Face Geometry Differences: Male vs. Female

- With males, the gonion breadth is increased by 3.4 cm compared to females
- Similarly, the menton is located lower by 1.4 cm compared to females
- The tragion and zygion breadth is increased by 1.2 and 1.0 cm
- Both the sellion and glabella positions are located forward by 0.8 cm

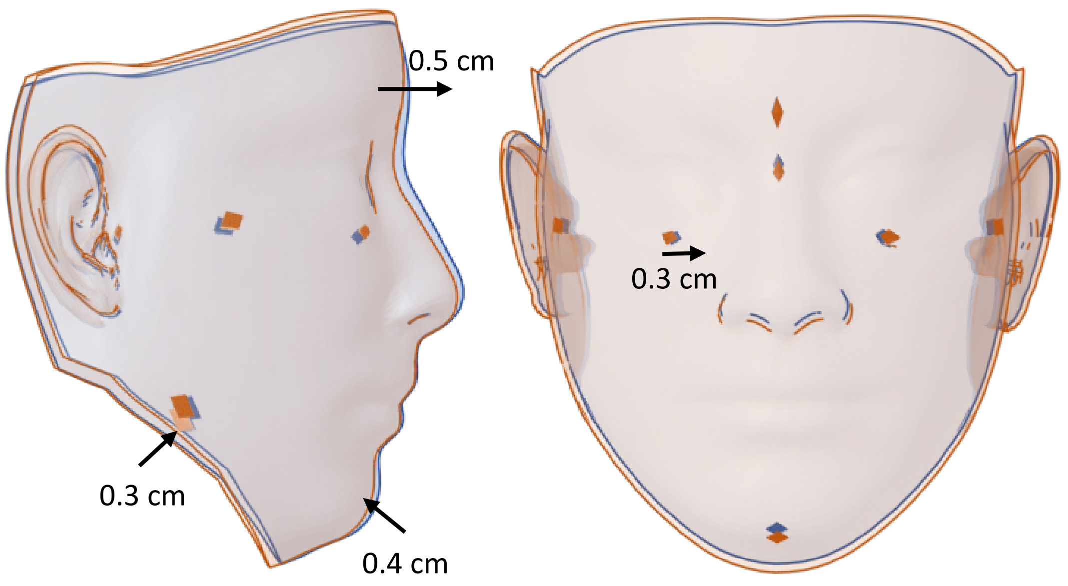


Face template morphed by landmarks
Female vs. male average, ethnicity controlled

Landmark and Face Geometry Differences (Cont'd):

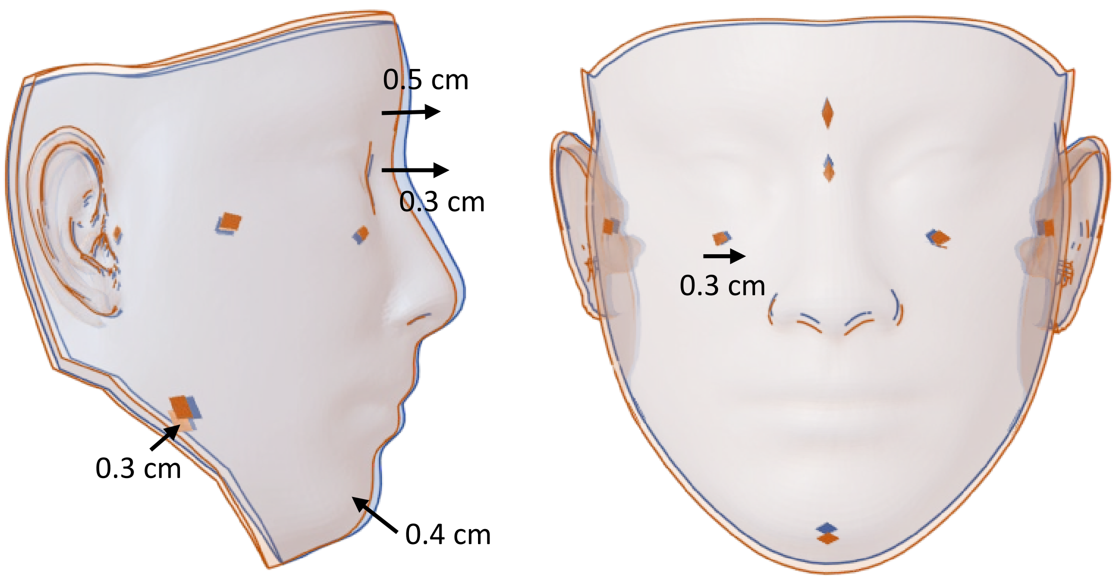


Black vs. White
Gender controlled

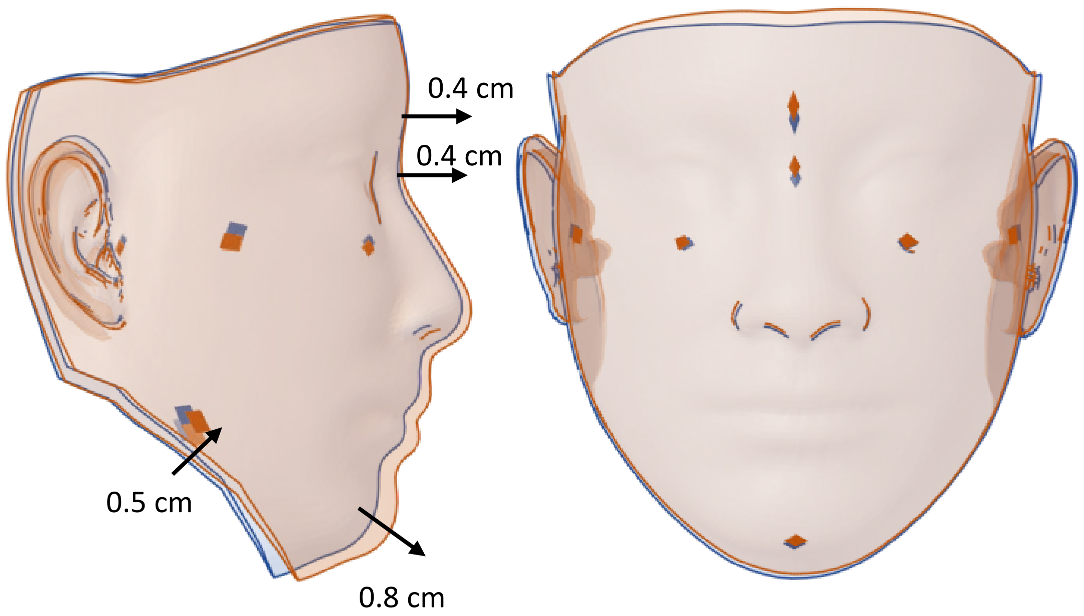


Hispanic vs. White
Gender controlled

Landmark and Face Geometry Differences (Cont'd):



Asian vs. White
Gender controlled



Black vs. Asian
Gender controlled

Conclusion

- There were significant changes between ethnic and gender groups with respect to face shape.
- Gender was the major driving factor for face shape, but ethnic variations were present and is important to consider for optimizing equipment fit design parameters.
- Future work will consider a range of face poses to capture non-neutral face shapes such as when talking, eating, or yawning.