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FACIAL SHAPE INHERITANCE ANALYSIS USING CENTROID SIZE : A GEOMETRIC MORPHOMETRIC STUDY

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ABSTRACT : Facial shape assessment, besides being important for forensic identification purposes, is also used in various fields, such as orthodontics, maxillofacial surgery, plastic surgery and clinical genetic. The inheritance of the facial shape is affected by genetic and environmental factors. The method widely used to measure the size and shape of the face is the anthropometric method, but this method is considered inadequate to accurately define the facial shape. The study aims to analyze the inheritance of facial shapes in Austronesian populations using geometric morphometric method. The research was performed in 14 families consisting of 77 subjects with details of 32 subjects of the first generations (G1), 28 subjects of the second generations (G2) and 17 subjects of the third generations (G3). The subjects consisted of 28 men and 49 women aged between 17 and 86 years. The frontal photo was taken and then processed through the tpsUtil, used 25 landmark points that were put through the tpsDig and then geometrically morphometrically analyzed using the morphologika2 v2.5 program. A one-sample binomial test was performed using the log (ln) centroid size value for each family using IBM® SPSS® Statistics Version 26. Results**: The results of the one sample binomial test showed no significant differences in the 14 families. In conclusion, no significant differences in the log (ln) value of the centroid size in all families have shown that the facial shape is inherited.**

Key words : Facial shape, inheritance, geometric morphometric.

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INTRODUCTION

The development of the human face is generally used as the basis for variations in a population's facial characteristics. In general, apart from being affected by genetic factors, craniofacial bone morphology is also affected by environmental factors. Craniofacial anthropometry is used to determine the morphological character of the head and face as an essential element of anthropology and medical fields. Craniofacial size study is usually carried out to compare different populations or to compare the sexes (sex determination). In various fields, such as plastic surgery and orthodontics, analysis of the facial size and shape is carried out using both metric and non-metric. It is also used to diagnose congenital abnormalities. For forensic purposes, there is hardly any study on facial analysis, although there are some who state the benefits and disadvantages of assessing facial size and shape. Facial classification can assist with biological profile identification, facial reconstruction and comparative information from photographs (Ritz-Timme *et al*, 2011).

Previous study on 38 Korean families using two-dimensional digital photos showed significant family correlations across 13 facial anthropometric measures (Kim *et al*, 2013). The inheritance of facial soft tissue patterns using frontal and lateral photographs in 140 people from 35 families consisting of fathers, mothers, sons and daughters. The research was conducted by tracing photos to test the correlation of linear and proportional parameters from parent to child. The results show that the inheritance of boys to mothers is greater than that of fathers, while girls show the same one to both parents. The researcher then concluded that the shape of the child's facial soft tissue could be predicted from parental data (Lahoti *et* *al*, 2013).

It is now possible to observe the character of human craniofacial shape variations using geometric morphometric methods. Using numerical or visual aspects, the pattern of facial shape variation can be described and measured, because the geometric morphometric method allows the results of statistical analysis of a shape to be visualized as a shape transition. This approach provides a clear interpretation of geometric statistical analysis so that the problems faced when conventional anthropometric analysis is used can be overcome (Hennessy and Stringer, 2002). In this study analyze the shape of a biological object is usually a series of measurements of distances and angles in conventional multivariate morphometrics. A series of measurements are linked to the shape of an object by the geometric morphometric method. Furthermore, the aim of this study is to use geometric morphometric methods to analyze the inheritance of facial shape in Austronesian populations.

MATERIALS AND METHODS

This study was a cross-sectional analytical observation, where exposure was measured at the same time. The research sample was taken based on the criteria: Austronesian population based on genealogy without mixed marriages up to three generations, a family consisting of three generations, aged at least 17 years (Bishara, 2005). Moreover, the sample does not have craniofacial abnormalities either due to congenital defects or trauma, and has never received orthodontic treatment or plastic surgery on the face. There were 14 families with a total of 77 subjects, consisting of 32 generation 1 (G1) subjects, 28 generation 2 (G2) subjects and 17 generation 3 (G3) subjects, based on these criteria.

Furthermore, an ethical test was carried out through the Health Research Ethics Committee of the Faculty of Dental Medicine, Universitas Airlangga, Surabaya, Indonesia, with the certificate number: 280/HRECC.FODM/XI/2017. To obtain the sample, the author initially distributed questionnaires to subjects who met the criteria and filled out an informed consent form. Then the photo was taken from the anterior direction with the lateral position of the face parallel to the Frankfurt Horizontal plane. The photo was taken outside of the room when the sunlight is bright enough. The author prepared a white X-banner as a screen with a printed scale lengthwise on the right, then a chair without a back was placed right in front of the screen. In addition, with a distance of 1.5 m from the screen measured by a tape measure, the camera and tripod are prepared. If the subject has long hair, the hair is tied back so that the ears and forehead are clearly visible. The subject sat upright, looked straight at the camera, mouth closed without a smile with a relaxed occlusion position. To avoid biased frontal photos, the position of the face / head is adjusted so as not to look down or look up (head pitch) and not look left or right (head turning). Meanwhile, head tilting, which is the position of the head tilted to the left or right, will not have an effect because a rotation will be carried out during the Procrustes Analysis (Hayes, 2009; Hinterleitner, 2013).

The results of 2 D photos were stored and processed using tpsUtil. The facial shape to be analyzed includes facial outline and the composition of the eye, nose and mouth positions that are part of the face. To get the intended face shape, twenty-five landmark points (Fig. 1) were used which were placed on the photo by tpsDig. Then the data were analyzed using morphologika2 v2.5 (Hayes, 2009; Schutz, 2007). The centroid size value for each family were analyzed using IBM® SPSS® Statistics Version 26.

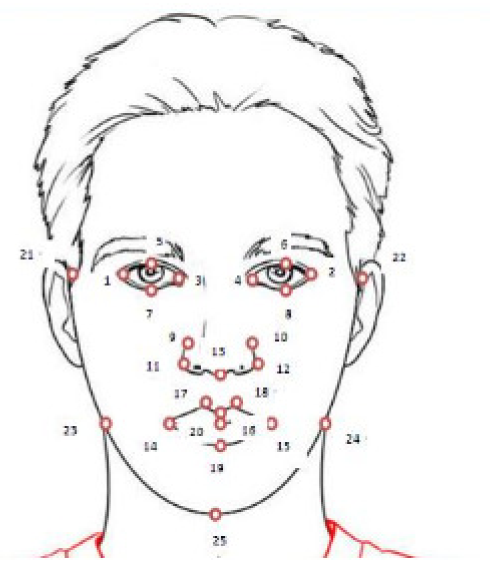

Fig. 1 : Twenty-five landmark points which were used in this study.

RESULTS

Table 1 shows the number of subjects in each generation, generation 1 (G1) is the grandfather and / or grandmother (of the father and mother), generation 2 (G2) is the father and mother while generation 3 (G3) is the child. The normality test was carried out to determine the distribution of the data, then a test was performed for each family using the log data (ln) centroid size (Table 2). Based on the normality test, it turns out that data are not normally distributed, so the non-parametric one sample binomial test is used. Table 3 shows that there are no significant differences in all family groups with a significance value> 0.05.

Table 1 : Number of generations and total number of each generation.

Generation (G)	N	Percentage (%)
1	32	41.6
2	28	36.4
3	17	22.1
Total	77	100.0

Table 2 : Normality test.

	Family	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Log centroid	1	0.368	6	0.011	0.709	6	0.008
	2	0.330	7	0.020	0.718	7	0.006
	3	0.273	5	0.200*	0.890	5	0.358
	4	0.250	6	0.200*	0.923	6	0.526
	5	0.281	5	0.200*	0.910	5	0.470
	6	0.343	5	0.055	0.758	5	0.035
	7	0.255	6	0.200*	0.920	6	0.504
	8	0.250	6	0.200*	0.876	6	0.251
	9	0.200	5	0.200*	0.937	5	0.646
	10	0.201	5	0.200*	0.945	5	0.699
	11	0.235	5	0.200*	0.963	5	0.826
	12	0.209	5	0.200*	0.936	5	0.639
	13	0.348	5	0.048	0.804	5	0.087
	14	0.240	6	0.200*	0.901	6	0.377

*This is a lower bound of the true significance.

Table 3 : One-Sample Binomial test.

Family (F)	N	Asymptotic Sig.(2-sided test)
1	6	0.221
2	7	0.450
3	5	0.371
4	6	0.221
5	5	1.000
6	5	0.371
7	6	0.683
8	6	0.683
9	5	1.000
10	5	0.371
11	5	1.000
12	5	1.000
13	5	0.371
14	6	1.000

Value <0.05 indicates a significant difference in the group.

DISCUSSION

In various medical fields, such as orthodontics, maxillofacial surgery, plastic surgery, as well as clinical genetics, analysis of the size and shape of facial soft tissue is widely used (Moshkelgosha *et al*, 2015). Furthermore, facial analysis in the forensic field is also needed for identification purposes. In order for facial identification to be more precise, knowledge of facial features is required both in general and specifically in a population, and this is easier to do by using facial photographs (Roelofse *et al*, 2008).

This study is a family study conducted in each family over three generations, with the first generation (G1) being the grandfather and/or grandmother, who both father and mother come from. The aim was to analyze the inheritance of facial components. Previous study that has been conducted is research conducted on siblings or between parents and children. According to Mayhew, a family study involving family members outside the main family can minimize shared environmental factors (Mayhew and Meyre, 2017).

Facial morphology consists of a number of characters that are relatively complex and affected by genetic and environmental factors. Facial growth and development starts at week 4 of pregnancy, so that the developing fetus can be affected both at home and at work by adverse environmental impacts, or it can also be caused by the activities or lifestyle of the mother In addition, environmental factors that can have a significant impact on facial development, which in turn will affect facial morphology, are stochastic factors such as facial trauma, pathological conditions and surgical procedures (Moore and Persaud, 2013; Richmond *et al*, 2018).

The geometric morphometric method is based on the

Cartesian coordinates of landmark points, unlike the classical morphometric approach, which is based on lines, distances and angles. Landmark has a name and a position consisting of two or three coordinates, expressing certain similarities across all measured specimens. The size most commonly used in geometric morphometric is the centroid size (CS) (Mitteroecker and Gunz, 2009; Mitteroecker *et al*, 2013).

Morphologika2 through Procrustes Registration eliminates differences in scale, position and orientation. Initially by calculating the centroid of a shape or center of gravity, *i.e.* calculating the average of the overall x and y coordinates of a shape (Σ x, y / number of landmarks). The resulting average of the coordinates is the centroid of a shape. The next stage of the Procrustes Registration process is to calculate the centroid size of each shape, which is the square root of the sum of the square distances of the entire landmark from the centroid. The sharing of landmark data via the centroid size for each shape results in a series of scalable shapes that can be compared but still retain their own shape information. Once scaled, a series of shapes is then translated by positioning the centroid at the center of the xy coordinate. This is done by subtracting the centroid value of the coordinates of the overall landmark. Furthermore, every shape's coordinate data is rotated. At this stage, until all coordinates are aligned, the coordination landmark is rotated around the centroid. This is done by minimizing the sum of square distances between each shape's landmarks (Hayes, 2006).

Location differences are eliminated by centralizing the configuration, which is to calculate the centroid of each configuration and make the centroid the center of the new coordinate system. The difference in size is eliminated by rescaling each configuration so that it shares the same centroid size. The difference in orientation between the two configurations is eliminated by rotating a configuration (target) around its centroid until it shows the location of the landmark which is relatively the same as the other configuration being reference. The procedure of translating all landmark configurations to the same location, rescaling all configurations to combine the centroid sizes, and rotating all of them to the least square that is parallel to the reference mean that is estimated repeatedly is called Generalized Procrustes Analysis (GPA). Since all differences in location, scale, and orientation have been eliminated through this procedure, any difference in the coordinates of an appropriate landmark between configurations should be the result of differences in shape between the configurations (Webster and Sheets, 2010).

CONCLUSION

It can be concluded that there is no significant difference based on the one sample binomial test using the log (ln) value of the centroid size of the facial shape in the 14 families, indicating that the facial shape is inherited.

Conflict of interest

The authors declare that they have no competing interests.

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