The Heredity of Cephalogram's Landmark Position in Javanese Population

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Summary
The heredity of children's physical characteristics from parents has been well documented, while the heredity of cephalogram's position of Javanese population from a generation to the next has not been yet studied. This research was conducted on 129 cephalograms from 43 families of Javanese population consisting of father, mother, and one biological child. Based on five cephalogram landmarks: Nasion, Orbitale, PointA, Sella, and Porion, a triangle was formed to find the measure of each angle subsequently. The triangle similarity theory is used to compare each angle of a child's triangle with its parent with a standard deviation threshold of 129 cephalograms for each angle. The children triangle could be said similar to the parent's triangle if the margin of each angle is smaller or equal to the standard deviation. The results showed that only one child had ten similar triangles to the parents, as much as 28 families had 5 or more similar triangles to the parents, and the rest had less than five similar triangles. In other words, out of 43 families, 29 families (67%) with 5 or more triangles were similar to their parents' triangles. The comparison also conducted to the parent triangles of 43 families with the children triangle to obtain inconsistency number. In average, 19 triangles (45%) of 43 children are not similar to the parent triangles. From these results, it could be concluded that the comparison of each family and cross-family had 67% and 55% similarity respectively. These results were obtained due to Javanese people had similar physical characteristics. Thus further research was needed by comparing with other ethnic group populations.
Keywords:
heredity; cephalogram; landmark; triangle similarity; Javanese population.

1. Introduction

The heredity of children characteristics coming from the parent can be seen in their physical body such as shape and color of hair, skin color, eye color, eye shape, nose shape, and so forth. However, in addition to the physical characteristics, many features such as blood type, color blindness, the number of chromosomes, disease, and personality are also inherited from the parents. Physical characteristics heredity has well documented as in [1] the analysis of heredity of craniofacial features in Colombian families with class III malocclusion, or [2] the analysis of Heritability of craniofacial characteristics between parents and offspring estimated from lateral cephalograms. The use of triangle theory in this research is to determine a skull bone gender by analyzing Mastoid triangle and Opisthion-Bimastoid triangle [3].
The theory of triangles similarity is also used in this paper by using each angle's from the triangle. The triangle formed from the three landmarks on a cephalogram can not be the same as that of formed from the same three landmarks on the other cephalogram. Thus, a threshold is needed to determine the tolerance limit of the triangle difference which formed in the same landmark with different cephalogram. From the analysis, the results of triangular similarity of the parents to their children will be presented. Hence, that will be revealed whether the cephalogram position is inherited from the parents to their children or not.

2. Cephalogram's Landmark Position

The lateral cephalogram is the photographed side view of a person's head by using an x-ray that shows the teeth, soft tissues, skull features and components [4]. Cephalogram or also called the cephalometric radiograph is the x-ray image of the head obtained from a fixation called the cephalostat which records the skull, dentition, and soft tissue features of the head [5]. The first study regarding the automatic detection of cephalometric landmarks dates back to 1986 by Levy-Mandel et al. [6]. A knowledge-based framework is offered in the paper. The algorithm starts with filtering step for noise reduction and image enhancement. In this step, median filter, the histogram equalization process and the sharpening filter applied to the image. After that edge detection is conducted using Mero-Vassy. Finally, a line-following algorithm is applied to the system with a predefined set of rules and a simple interpreter. The algorithm aims to extract only significant lines not the positions of the landmarks. The algorithm was applied to x-rays, and 23 out of 36 landmarks detected. Parthasarathy et al. [7] suggested the image pyramid method based on Levy-Mandel to reduce processing time. Similar to Levy-

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Mandel, a median filter is used for preliminary filtering, histogram equalization for improving the contrast but different gradient operators are used to improve edges. In this way, they aim not only to extract the significant lines but also to identify the location of the landmarks. The proposed method was tested, and out of 9 landmarks, 18% was detected with an error below 1 mm, 58% below 2 mm and 100% below 5 mm. Cardillo and Ahmed [8] used the pattern-matching techniques based on gray-scale mathematical morphology for identifying landmarks. The system was trained to find 20 landmarks. The algorithm ran on 40 x-ray images, 85% rate of recognition was achieved. In other study about automatic landmark detection [9], mathematical morphology techniques based pattern detection algorithms are used. The systems detected 17 landmarks on 20 images, and have a success rate over 90%. In the study of El-Feghi et al [10], neuro-fuzzy system and template matching methods are used. The system is trained for 20 cephalometric landmarks on 565 cephalogram images in the database, and preliminary results show that the rate of perception is more than 90%. Rahele Kafieh et al. [11] used Susan Edge Detector, ASM, and template matching methods for detecting landmarks. Cellular Neural Networks are used in [12] and ten landmarks are detected on 41 x-ray images. In the study by S.Shahidi et al [13], 16 landmarks were selected for detection. They used template matching and edge enhancement methods and identified 12.5% of landmarks with the mean error below 1 mm, 43.75% below 2 mm. The mean error of all cephalometric landmarks excluding Anterior Nasal Spine was below 4 mm. Many new state-of-the-art methods have been proposed in recent years. Claudia Lindner et al [14] have developed a fully automatic system (FALA) for finding cephalometric landmarks. In the system, the researchers applied Random Forest Regression-voting to detect the position, scale and orientation of the skull. This process makes the framework robust to any variations in image acquisitions. After that Constrained Local Model (RFRV – CLM) is used to locate landmarks. The framework achieved 84.7% of landmark localisation within the clinically accepted precision range of 2.0 mm. To overcome the limitations of the problem, three dimensional surface models have often been used [15]–[18]. Marina Codari et al [15] developed a semiautomatic computer-aided cephalometric landmark annotation for Cone Beam Computerized Tomography. The framework is based on 3D cephalometric analysis that estimates the three dimensional positions of 21 cephalometric landmarks. Adaptive cluster-based segmentation of bone tissues is applied followed by an intensity based registration of an annotated reference volume. Experimental results show that annotation error was less than 5.00 mm for 90 % of landmarks and less than 2.50 mm for 63 % of them.

3. Research Method

The research stages are shown in Fig. 1 which starts from finding volunteers as a research sample. The study is conducted in Yogyakarta where most of the people were Javanese. The lateral cephalogram of Javanese population was collected from 50 families consisting of father, mother, and one biological child with age over 14 years. All volunteers were required to fill in a questionnaire including personal data; name, place of birth, address, parent's name, weight, hair color and shape, skin color, staple and non-staple food, head shape, eye shape, nose shape, lips, ear shape, chin shape, cheek shape, and upper and lower teeth. All these questionnaire data are tabulated in Microsoft Excel files for data source records.

Then all volunteers got their head photographed to collect the lateral cephalogram. The radiograph is conducted at Prof. Soedomo Dental and Oral Hospital (RSGM), Faculty of Dentistry, Universitas Gadjah Mada, Yogyakarta by using Unipanocephalostat with x-ray Texco activator. The cephalostat works by directing the x-ray beam through the left side of the head, and the projections are captured by a film plate which will be scanned on a VistaScan Omni Plus scanner to produce a lateral cephalogram file in JPG format. Each file is stored with a naming format containing serial number 1, 2 and 3 of father, mother and child respectively. For example, the file name JAWA0011.JPG is the 1st family file as the father; JAWA0012.JPG as the mother and JAWA0013.JPG as the child.

The software used is C# programming which enhancing the cephalogram, while indicating each landmark as well as determining the Region of Interest (ROI) were done manually by orthodontics who specialist in malocclusion treatment (Sp.Ort (K)). Of the 150 cephalograms, 129 cephalograms of 43 families were selected. The cephalograms of the seven families were not used because they had either partial or complete tooth decay, or dentures. The specialists then marked ten landmarks and the surrounding area that is known as the Region of Interest (ROI). The software stores the marking results into an XML file containing the cephalogram size, the coordinate position of 10 landmarks, and the area size of each landmark. The XML file formed was converted to an XLS (Ms. excel) file to make the process easier.

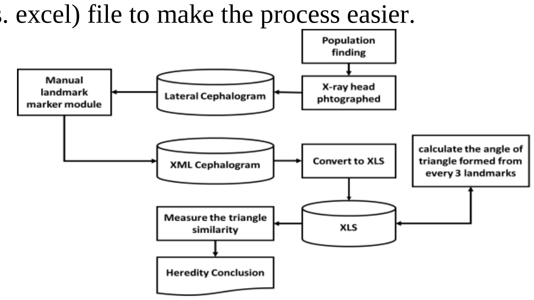

Fig. 1 Research stages

In this research, a dentist of cephalometric specialist from UGM Prof. Soedomo Dental and Oral Hospital (RSGM) Yogyakarta was involved to obtain an accurate landmark position as the reference. The specialist applied his/her skills and knowledge to mark the landmark and ROI accurately. The marking was done manually by displaying the lateral cephalogram on the computer screen, and then the doctor marked the selected landmark along with the specified ROI as shown in Fig. 2 in which Sella and ROI were marked with a red box.

The doctor marked ten landmarks along with their ROI as shown in Fig. 3 and then each position was stored in an XML-formatted database.

Fig. 2 Module to mark the landmarks and ROI

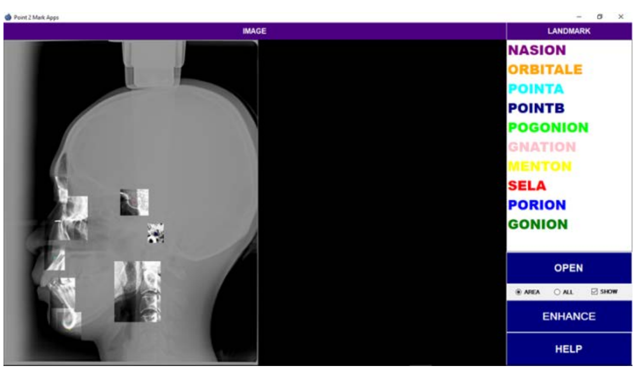

Fig. 3 The marked landmarks and ROI position

The marking results will then be used for the analysis of whether the parent landmarks position inherits to the child or not. The angles on the triangles formed on a cephalogram will be compared with the angles of the other cephalogram triangles by specifying a certain threshold so that the triangle can be said as similar. If the triangle between these cephalograms is similar, then it can be concluded that the parents inherit their cephalogram landmark position to their child.

Before forming the triangles, conducting a calculation of the distance (d) between landmarks is first needed. If the landmark coordinates are located at $p(p_1, p_2)$ and other landmarks in $q(q_1, q_2)$, thus the distance between them, notated as d can be determined using (1).

$$d(p,q) = \sqrt{(q_1 - p_1)^2 + (q_2 - p_2)^2} \quad (1)$$

The distance calculation is only applied on five landmarks named Nasion, Orbitale, PointA, Sella and Porion landmarks as long as the landmarks are in the cranial plane whose static position. Other landmarks of PointB, Pogonion, Gnation, Menton, and Gonion are not calculated as the landmarks are located in the mandibular plane whose dynamic growth that influenced by external factors such as nutritional intake or accidental or collision changes. After the distance of each landmark is obtained, then the triangles of each three landmarks are formed. By using the mathemathic combination formula 3 of 5, each angle of ten triangles is measured. If the number of points is five pieces which denoted by n, it will be formed into triangles requiring 3 points that denoted by k, which then a 3 of 5 combinations is obtained by using (2) where n is the number of landmarks used to form triangles and k is the number of all lanrmarks used. Then ten triangles are produced, as shown in Fig 4.

$$C_k^n = \frac{n!}{k!\,(n-k)!} \quad (2)$$

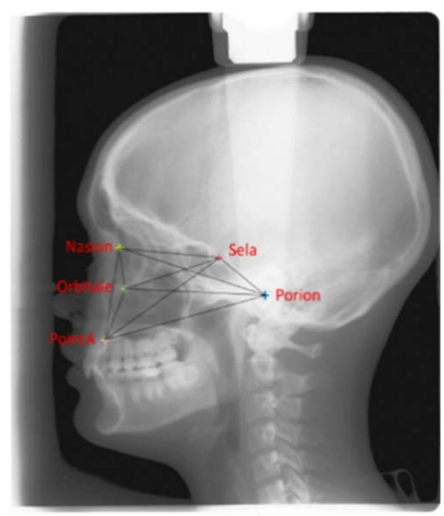

Fig. 4 The triangle from each connected landmarks

After ten triangles have been obtained, each angle is measured by using the distance of each triangle side (a,b,c) and applying the Cosinus rule as in (3) to get the magnitude of the angle.

$$\cos\theta = \frac{b^2 + c^2 - a^2}{2bc} \tag{3}$$

Ten formed triangles of a cephalogram will have a similar shape to ten formed triangles of another cephalogram since the position of the cephalogram landmarks has its particular location, such as the Orbitale which is the lowest point on the lower edge of the orbital bone. This fixed landmark location that causes a triangle is formed from 3 pieces of landmarks on a particular cephalogram which already looks similar to a triangle on another cephalogram. The similarity of this triangle will be used to determine whether the position of a landmark is inherited from the parent to child. Ten triangles are made using five landmarks symbolized by N: Nasion, S: Sella, O: Orbitale, PA: PointA, P: Porion can be seen in Fig. 5.

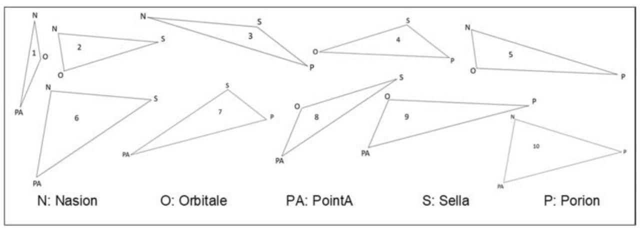

Fig. 5 Ten triangles of five landmarks

The triangle similarity can be obtained by comparing two triangles to the angle size and length of each side based on the triangle similarity theory as seen in Fig. 6 and (2) and (3).

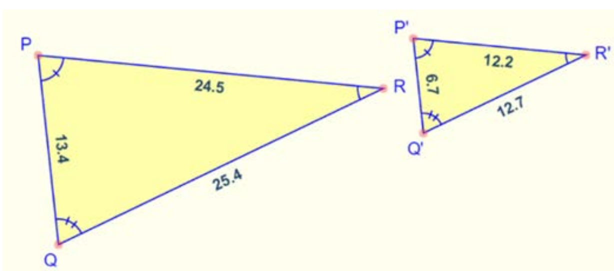

Fig. 6 Similar triangles

$$P = P', Q = Q', R = R' \tag{2}$$

$$\frac{PQ}{P'Q'} = \frac{QR}{Q'R'} = \frac{RP}{R'P'} \tag{3}$$

Every angle obtained from each parent triangle (father and mother) is compared to every angle obtained from each of their child triangles. The possibility of the same angle size in the parent triangle and of the child triangle is so small so that a threshold is required to limit how much the angle difference between the parent and child triangles to be called as similar. In this study, the threshold used is a standard deviation (Table 1) from each corner of the 129 cephalograms from 43 families.

Table 1:. The standard deviation of each angle from ten triangles

Triangle	Angle 1	Angle 2	Angle 3	Average
N-O-PA	5.01651	8.32769	3.86989	5.73803
N-O-P	4.96092	5.81893	1.88104	4.22030
N-O-S	5.05729	5.56301	2.93910	4.51980
N-PA-P	4.98896	2.47343	4.55653	4.00631
N-PA-S	4.83346	3.72520	3.28672	3.94846
N-S-P	3.42466	6.30369	9.24386	6.32407
O-PA-P	7.01137	2.26705	6.02711	5.10184
O-PA-S	6.68979	2.50488	5.05316	4.74928
S-PA-P	9.02500	3.33408	7.35195	6.57034
S-O-P	9.27298	4.24874	6.45178	6.65783
			Average	5.18363

The diagram in Fig. 7 illustrates that for every corner of the triangle, in addition to being compared to a family, it is also compared with other families. In other words, the angle of child triangle from a family will be compared with the angle of the father or mother from another family as to calculate how many children triangles have a different angle to the other 43 families.

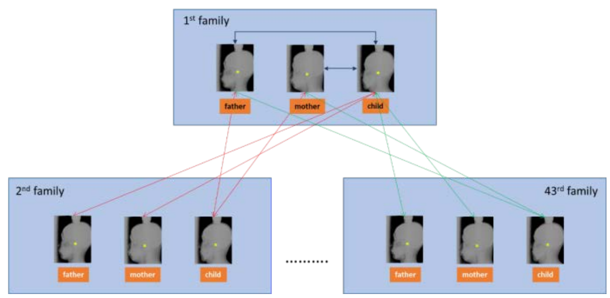

Fig. 7 Comparison of child's triangle with father's or mother's triangle

Ten triangles of children are measured and compared with ten father or mother's triangles to determine whether the landmarks position of cephalogram inherited from the parent to child by using a triangular similarity algorithm check shown in

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For 43 families:
    For 10 triangles:
    Calculate each A1, A2, A3 corner of 129 cephalograms
    For each A (Angle):
        If (Abs (Father Angle - Child Angle) <= A .OR. Abs (Mother Angle - Child Angle) <= A)
            Score = 1 (similar triangle)
        EndIf
    If Score> = 5
        Landmark position is inherited (more than 50% of similar triangles)
    EndIf
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Fig. 8 Algorithm of landmark position heredity

4. Results and Analysis

The triangle is used as a tool to determine whether the landmarks position of parents (father or mother) inherited to their children using five landmarks namely Nasion (N), Orbitale (O), Point A (PA) and Porion (P) which formed ten pieces of the triangle as shown in Table 2.

The similar triangles of each family are shown in Fig. 9 which shows 29 families (67%) of 43 families have a similar triangle of five or more (above 50%). Even the 25th family, ten children triangles are similar to the father or mother triangle.

Table 2: Ten triangels formed from five landmarks

1.	N	-	O	-	PA
2.	N	-	O	-	P
3.	N	-	O	-	S
4.	N	-	PA	-	P
5.	N	-	PA	-	S
6.	N	-	S	-	P
7.	O	-	PA	-	P
8.	O	-	PA	-	S
9.	S	-	PA	-	P
10.	S	-	O	-	P

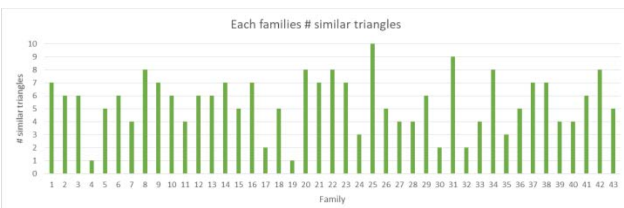

Fig. 9 Graph of the similar triangles from 43 families

To support the conclusion, the parent triangle is also compared to the child triangle from other's families . The results showed that 55% triangles are similar and 45% of which are different. The result initially is expected to be different, yet in fact, it is similar. For example, the parent's triangle from a family is compared to 43 children triangle. The result revealed 20 children who had the same triangle, and the other parent's triangle was also compared to 43 children triangle, of which there were 24 similar triangles of children, and so on as shown in Fig. 10.

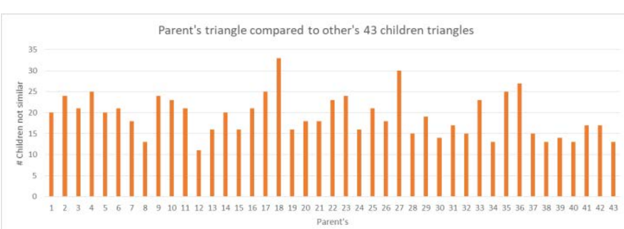

Fig. 10 Graph of Comparison on the parents' triangle to other's 43 children triangle

5. Conclusion

Ten similar triangles of each cephalogram, visually, had a similar shape but after conducting calculation based on triangle theory, there were large size differences from each angle. The average deviation standard of 5.183623 degrees also showed visually that the triangle formed had a close similarity. The result of calculation and comparison between 10 children triangles with ten father's and mother's triangles from 43 families were found that 29 families (67%) had similar children's triangles with his father or mother triangle. In the comparison of parent triangles with 43 children from different families, a similarity rate of 55% was obtained. Thus, both similarities of the comparison between the parent triangle to their children and the parents' triangle to other children from different families had similarity rate of above 50%. This obtained result was because the sample used was from Java population which their physical figure and race do have similarities. Further research can be done by comparing with other populations of ethnic groups as well as calculating the distance of each triangle side to obtain a better resemblance.

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