SciMedCentral

Annals of Forensic Research and Analysis

Research Article

Human Variation in Face Aging in Adult Monozygotic Twins: Biometric Implications for the Forensic Sciences

A Midori Albert[1]* and C Chad Lloyd[2]

[1]Department of Anthropology, University of North Carolina Wilmington, USA
[2]Department of Chemistry, University of North Carolina Chapel Hill, USA

Abstract

This study examined the extent of similarity and divergence in facial appearance of adult monozygotic (i.e., genetically identical) twins as a function of age. Variation in face aging is relevant to advancing technologies in computer automated face recognition and age progression in the forensic sciences. The focus was on the influence that epigenetics had, if any, on the divergence of facial similarity, assessed by evaluating facial dimensions of adult monozygotic twins. The sample comprised high - resolution digital images of 65 twin sets aged 18 to 78 years, male and female, separated into three age groups (young, middle, and older adult). A reference sample of sub adult monozygotic twins (aged 6 to 18 years) was used for comparison. The digital images were landmarked and measurements were taken for several dimensions of the face. The data were analyzed to determine what dimensions of the face may show significant divergence as identical twins age. Results suggest that the role of epigenetics in face aging remains unclear; there was a high degree of variation with some twin sets' facial appearance being more similar, while others showed significant divergence, seemingly independent of adult age.

***Corresponding author**

A Midori Albert, Department of Anthropology, University of North Carolina Wilmington, 601 S. College Road, Wilmington, NC, 28403, USA, Tel: 910-962-7078; Fax: 910-962-3543; Email: albertm@uncw.edu

Submitted: 12 July 2016

Accepted: 03 August 2016

Published: 04 August 2016

ISSN: 2378-9476

Keywords

- Face aging
- Facial appearance variation
- Monozygotic twin variation
- Epigenetics
- Forensic science

INTRODUCTION

Intrinsic (biological) and extrinsic (environmental) factors are known to significantly affect human variation in face aging, and an understanding of these factors has, over the years, contributed to the development of, and improvements in, computer automated face recognition and facial age progression technologies in the forensic sciences [1]. There are definite genetic markers that affect face aging [2,3], and the phenomenon of epigenetics, or the compilation of genetic mutations that occur in DNA as an individual ages, may play a role in the changing appearance of the aging face. Epigenetic modifications result in miniscule changes in gene expression, which can change anything from one's appearance to the way an individual behaves.

It was not until 2002 that the importance of epigenetics in twins was demonstrated [4]. Before 2002, monozygotic twins were believed to have identical DNA throughout their lifetimes; and any discrepancy in phenotypic appearance was considered a direct result of environment. However, recent research has shown that monozygotic twins have identical DNA when they are born, yet they develop and accumulate different DNA strands as they age [4-6]. Epigenetics can help explain why there may be variability in identical twins and how facial features of such twins may diverge in similarity of appearance over time.

Inasmuch as computer automated face recognition and age progression research endeavors to understand patterns in face aging to improve accuracy, the extent to which epigenetics could be involved in face aging is key. This was the impetus behind this present study. The approach to this research question was based in part on earlier research conducted on subadult monozygotic twins. Naini and Moss [7] studied the effects of epigenetics on the facial development in subadult monozygotic twins (6-18 years old). By way of understanding the relevance of epigenetic factors on subadult monozygotic twins, and that epigenetic factors have more of an effect on the DNA over time (i.e., as individuals age), due to the length of time that has passed allowing these epigenetic factors to set in, then it can be assumed that these factors will appear more pronounced in adult identical twins.

The present study involved an examination of a sample of face images of adult identical twins (n = 130) to determine whether epigenetic factors could play a role in the divergence of facial similarity over time, where it was hypothesized that twins would appear more dissimilar the older they become.

Hypotheses were developed for areas of the face that may retain similarity as to those that may be expected to change, based on a review of the literature [1,7] and anecdotal evidence of the aging face. The area that was hypothesized to show the most similarity between identical twins was the triangular area demarcating the eyes and nose, based on the Naini and Moss study [7]. It was hypothesized that the same measurements that showed statistically significant differences in subadult twin sets (i.e., deviation in facial similarity) would also show differences in adult twin sets, that certain facial dimensions that deviated in subadults would continue to deviate as twin's age across the adult lifespan. It was also hypothesized that other areas of the face would continue to diverge as adult twin's age, and that they would show statistically significant deviations at later stages in life due to degenerative changes and where epigenetic factors have a chance to establish themselves (and accumulate) in individuals.

It was hypothesized that the following features would show statistically significant differences with aging (please refer to Table (1) and Figure (1)):

1. Right Alar Base to Left Alar Base
2. Soft Tissue Nasion to Subnasale
3. Subnasale to Labiale Inferius
4. Labiale Superius to Stomion
5. Labiale Inferius to Stomion
6. Labiale Superius to Labiale Inferius
7. Left Cheilion to Right Cheilion
8. Stomion to Sublabiale
9. Sublabiale to Soft Tissue Pogonion

It was hypothesized that the following measurements would show no major divergence between twins in a twin set (please refer to Table (1) and Figure (1)):

1. Lateral to Medial Canthus of Left Eye
2. Medial Canthus of Left Eye to Soft Tissue Nasion
3. Soft Tissue Nasion to Medial Canthus of Right Eye
4. Soft Tissue Nasion to Pronasale
5. Right Alar Base to Subnasale
6. Soft Tissue Nasion to Right Alar Base
7. Soft Tissue Nasion to Left Alar Base
8. Left Alar Base to Subnasale

The areas that were expected to show no statistically significant deviation have been found in previous studies to remain fairly constant (similar) throughout the adult lifespan [1,7]. Features such as inter orbital width do not change much in individuals, for example.

The objective of this study was to examine if any divergences in facial similarity could be measured as a function of age in adult monozygotic twins, who share the same genetic makeup, to better understand what role epigenetics may play in face aging.

Table 1: Landmark - based measurements used to analyze facial similarities and differences.

Measurement	Landmarks	Description of Landmarks
1	0-1	Right Eye Lateral Canthus to Right Eye Medial Canthus
2	1-2	Right Eye Medial Canthus to Soft Tissue Nasion
3	0-2	Right Eye Lateral Canthus to Soft Tissue Nasion
4	2-3	Soft Tissue Nasion to Left Eye Medial Canthus
5	3-4	Left Eye Medial Canthus to Left Eye Lateral Canthus
6	2-4	Soft Tissue Nasion to Left Eye Lateral Canthus
7	0-4	Right Eye Lateral Canthus to Left Eye Lateral Canthus
8	2-7	Soft Tissue Nasion to Pronasale
9	2-8	Soft Tissue Nasion to Subnasale
10	7-8	Pronasale to Subnasale
11	5-6	Right Alar Base to Left Alar Base
12	5-7	Right Alar Base to Pronasale
13	6-7	Left Alar Base to Pronasale
14	5-8	Right Alar Base to Subnasale
15	6-8	Left Alar Base to Subnasale
16	8-9	Subnasale to LabialeSuperius
17	9-10	LabialeSuperius to Stomion
18	10-11	Stomion to LabialeInferius
19	9-11	LabialeSuperius to LabialeInferius
20	11-12	LabialeInferius to Sublabiale
21	10-12	Stomion to Sublabiale
22	12-13	Sublabiale to Soft Tissue Pogonion
23	8-13	Subnasale to Soft Tissue Pogonion
24	2-13	Soft Tissue Nasion to Soft Tissue Pogonion
25	14-15	Right Cheilion to Left Cheilion
26	0-13	Right Eye Lateral Canthus to Soft Tissue Pogonion
27	4-13	Left Eye Lateral Canthus to Soft Tissue Pogonion
28	2-14	Soft Tissue Nasion to Right Cheilion
29	2-15	Soft Tissue Nasion to Left Cheilion

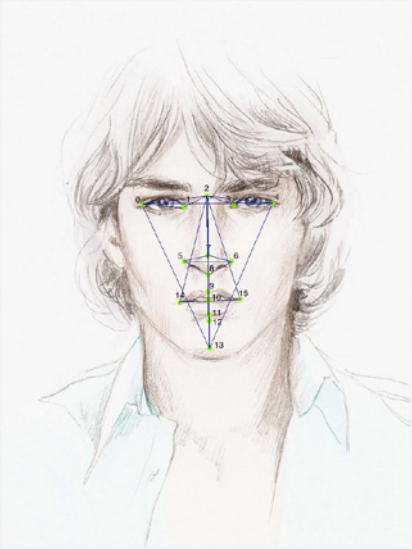

Figure 1 The 29 dimensions taken between landmarks [8].

MATERIALS AND METHODS

Sample

The sample for this study comprised 65 sets (or 130 digital images) of identical twin faces, which contained one image of each twin per twin set. The twin faces are part of the collection of biometric images labeled "ND – Twins -2009-2010", and are part of the UND Biometrics Database [9]. Of the 65 twin face sets, 13 were male and 52 were female. Since the sample sizes were too disparate between the sexes to get meaningful results, sex differences in aging patterns were not assessed.

The sample was split into three different age categories. Age Group 1 contained 17 twin face sets and ranged from 18-27 years old (to encompass individuals in the 20's). Age Group 2 was composed of 25 twin sets ranging from 37-51 years old (to represent those in the decade of the 40's). Age group 3 contained 23 twin sets that were 54-78 years old (to embody those that are age 50 years and older). The delineation for the age groups was based on where the most notable diachronic changes take place in an individual's lifetime [1]. By separating the sample into the above three age groupings, any patterns of facial similarity, or divergence of similarity, in twin sets that may be tied to an age - effect could be shown. Since aging is not necessarily a steady process, the age ranges chosen for this study help to emphasize decades where major changes typically occur in face aging throughout an individual's lifetime.

A reference sample was used to make comparisons between subadult and adult monozygotic twins. The face aging data from the above three age groups were compared to results of a study of facial similarity and divergence in subadult (6-18 years old) monozygotic twins conducted by Naini and Moss [7]. Naini and Moss [7] looked at changes in facial appearance of subadult monozygotic twins during growth and development, whereas the present study looked at the effects the aging process on adult monozygotic twins, essentially changes occurring over time, after growth and development has been completed. The sample for this study and the reference sample from Naini and Moss's [7] study on subadult monozygotic twins can be seen in Table (2).

Data collection: Land marking

In order to determine if there were areas of the face that deviate significantly in similarity of appearance in adult monozygotic twins over the course of the lifespan, measures of various facial dimensions were obtained (i.e., eye width, nose width, etc.). The approach to obtain and ensure accurate measures was to select a set of landmarks and "mark up" each face in the sample, meaning that for each digital image, fixed points on the image were added and this is known as "land marking" or "marking up" a face. Landmarks are standardized fixed points that are determined by anatomical features and are used in craniometric analyses. Each point on the digital facial images represents a coordinate in 2 - dimensional space with both an x and a y position. The face images were standardized at the time the photographs were taken. The landmarks for this study were well known and widely used because they represent key areas of the face used in measures of various dimensions to replicate face shape quantitatively. The landmarks can also be used in statistical analyses to help in sex or population classification in forensic cases of unknown human identity, for example.

The landmarks for the present study are identical to those in Naini and Moss [7] to allow for comparisons between the twin data sets - subadult and adult. Comparisons of the subadults and adults would take into account the notion that variation in facial dimensions in subadult twins is likely due to the processes of growth and development, whereas variation in facial dimensions in adult twins, who have completed growth and development, is likely due to "aging" in a degenerative sense. Once specific landmarks were chosen, a computer software program known as Face mark v. 2.0 [10] was used to overlay pinpoints on the digital images in the sample. "Marking - up" images involved placing landmarks on digital photographs of faces in the database. All 65 pairs of identical twins were marked up similarly. The landmarks begin with the number 0 and proceed to 15 sequentially as shown in Table (3) and Figure (2).

Data collection: Measurements

Measurements were taken between different selected pairs of landmarks and represent different facial feature dimensions. These measures were analyzed to determine where differences

Table 2: Sample of adult faces (present study) and reference sample of subadult faces (Naini and Moss [7]).

Age (Years Old)	# of Males	# of Females
Sub Adults (6-18)	5 twin pairs	5 twin pairs
Young Adults (18-27)	6 twin pairs	11 twin pairs
Middle - Aged Adults (37-51)	4 twin pairs	21 twin pairs
Older Adults (54-78)	3 twin pairs	20 twin pairs

Table 3: Landmark names and descriptions.

Landmark	Feature	Region/Description
0	Right Eye Lateral Canthus	Outside Corner of Right Eye
1	Right Eye Medial Canthus	Inside Corner of Right Eye
2	Soft Tissue Nasion	Area on Nose Directly Between Pupils
3	Left Eye Medial Canthus	Inside Corner of Left Eye
4	Left Eye Lateral Canthus	Outside Corner of Left Eye
5	Right Alar Base	Farthest Point on Right of Nose
6	Left Alar Base	Farthest Point on Left of Nose
7	Pronasale	Most Anterior Point on Nose
8	Subnasale	Point Where Nose Meets "Upper Lip"
9	LabialeSuperius	Point Where Upper Lip Truly Begins
10	Stomion	Point Directly Where Upper and Lower Lip Meet
11	LabialeInferius	Point Where Lower Lip Truly Ends
12	Sublabiale	Point of Maximum Concavity on Lower Lip
13	Soft Tissue Pogonion	Most Anterior Point on Chin
14	Right Cheilion	Right Corner of Mouth Where Lips Connect
15	Left Cheilion	Left Corner of Mouth Where Lips Connect

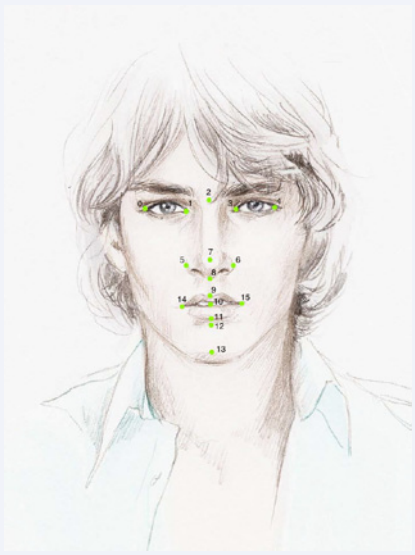

Figure 2 Example of landmarks on individuals in twin database [8].

might exist between twin pairs in the sample. The dimensions selected were made for ease of comparison of adults in this study to findings of subadults from Naini and Moss [7]. The measurements used are listed in Table (1) and illustrated in Figure (1).

A Python script (i.e., computer program) was written to transfer the data from Face mark v. 2.0 to a Microsoft Excel file, via a comma - separated variables file. The data were then organized and the measurements were taken as described above. Microsoft Excel was used to perform statistical testing of the data. Paired samples t - tests were run to determine if there were any statistically significant differences between the measurements for each age group and for all measures of facial dimensions between each twin, termed Twin A and Twin B, in each twin set. Findings from these statistical tests are discussed next.

Several statistical tests were employed to examine the data in different ways. At first, paired samples t - tests were performed for each measurement of a facial dimension for each age group, separately. For example, Measurement 1 was tested for all individuals in Age Group 1 to determine if Twin A and Twin B of a given twin set yielded results that were statistically significantly different.

RESULTS AND DISCUSSION

The measurements that showed statistically significant differences ($p < .05$) were Measurement 17 for Age Group 3, Measurement 19 for Age Group 3, and Measurement 21 for Age Group 1. Measurement 17 was the distance between the labialesuperius and the stomion (upper lip and space between lips, or upper lip thickness). Measurement 19 was the distance between the labialesuperius and the labialeinferius (upper and lower lips, or the thickness of both lips). Measurement 21 was the distance between the stomion and the sublabiale (space between lips and point of maximum concavity on lower lip, or lower lip thickness). The t - test results for Measurements 17, 19, and 21 can be seen in Tables (4-6) respectively ($p < .05$).

Results of statistical testing did not support the hypothesis that identical twins would continue to show divergence in similarity in the face throughout their lifetime. Each twin set was given a number (starting with 1 and proceeding through 65) and each twin in each of the 65 pairs was labeled Twin A or Twin B. A paired samples t - test was run for each twin pair (1-65) to determine whether or not the measurements from Twin A to Twin B within a twin set were statistically different or not. Table (8) in the Appendix gives the results obtained from the paired sample t -tests. Overall, 26 twin pairs were statistically significantly different ($p < .05$) from one another while 39 twin pairs did not show statistically significant differences. For Age Group 1, seven twin pairs were statistically significantly different ($p < .05$) while ten twin pairs did not show statistically significant differences (41%). For Age Group 2, nine twin pairs were statistically significantly different ($p < .05$) from one another while 16 twin pairs did not show statistically significant differences (36%). For Age Group 3, ten twin pairs showed statistically significant differences ($p < .05$) while 13 twin pairs were not statistically significantly different from one another (44%). Of the 13 male twin sets, seven showed statistically significant differences ($p < .05$) while six showed no statistically

Table 4: t-test for Measurement 17, Age Group 3.

t-Test: Paired Two Sample for Means		
	Variable 1	**Variable 2**
Mean	11.62478826	13.41744106
Variance	15.9199281	16.06252316
Observations	23	23
Pearson Correlation	0.645911253	
Hypothesized Mean Difference	0	
df	22	
t Stat	-2.554725415	
P(T <= t) one-tail	0.009032093	
t Critical one-tail	1.717144374	
P(T <= t) two-tail	0.018064187	
t Critical two-tail	2.073873068	

Table 5: t-test for Measurement 19, Age Group 3.

t-Test: Paired Two Sample for Means		
	Variable 1	**Variable 2**
Mean	24.20655866	27.79174636
Variance	60.5335868	65.21228698
Observations	23	23
Pearson Correlation	0.731043655	
Hypothesized Mean Difference	0	
df	22	
t Stat	-2.953790823	
P(T <= t) one-tail	0.003669172	
t Critical one-tail	1.717144374	
P(T <= t) two-tail	0.007338344	
t Critical two-tail	2.073873068	

Table 6: t-test for Measurement 21, Age Group 1.

t-Test: Paired Two Sample for Means		
	Variable 1	Variable 2
Mean	32.25540857	30.5421093
Variance	9.356150216	10.95077763
Observations	17	17
Pearson Correlation	0.526559092	
Hypothesized Mean Difference	0	
df	16	
t Stat	2.274354675	
P(T <= t) one-tail	0.01853248	
t Critical one-tail	1.745883676	
P(T <= t) two-tail	0.03706496	
t Critical two-tail	2.119905299	

significant differences (54%). Of the 52 female twin pairs, 19 showed statistically significant differences ($p < .05$) while 33 did not show any statistically significant differences (36%). Table (7) below shows the percent difference for each age group.

A Pearson's correlation was also run for the 65 twin sets to determine if twin sets at an older age had measurements that yielded a lower correlation between Twin A and Twin B than twin sets at a younger age, which could suggest greater divergence (less similarity) in facial appearance. If older twin sets had a lower correlation compared to younger twin sets, this would suggest that the measured dimensions between the landmarks deviate more as adult monozygotic twins age. However, the Pearson correlation was high (0.98-0.99) for all 65 twin sets, regardless of age. Interpretations of the findings are discussed presently.

Analysis of t-tests comparing facial dimensions among Age Groups 1, 2, and 3

The sample was divided into three age groups: Age Group 1 included young adults (18-27 years old) encompassing the effects of aging on twins in their individual measure of a facial dimension. There was one dimension that was found to be statistically significantly different ($p < .05$) for Age Group 1, the youngest age group, and two dimensions that were found to be statistically significantly different ($p < .05$) for Age Group 3, the oldest age group. All other measures did not show any statistically significant differences between Twin A and Twin B of a twin pair.

Measurement 21: stomion to sublabiale

Measurement 21 was found to be significantly different ($p < .05$) for Age Group 1. Measurement 21 was the distance between the stomion and the sublabiale; this is where the upper and lower lips meet to the point of maximum concavity on the lower lip (see Figure (2)). It is important to note that this dimension is statistically different for twins in Age Group 1, the youngest age group, but not for Age Groups 2 or 3, which were composed of older individuals. This suggests that the difference in this measurement becomes less pronounced over the course of an adult's lifespan, which is counter to the hypothesis that greater differences are evident due to advancing age. This could be explained by the ability to easily distort the lip regions by facial expression, which would lead to a difference in the appearance of faces in a photograph.

Measurement 17: labialesuperius to stomion

Measurement 17 was found to show a statistically significant difference ($p < .05$) for Age Group 3. Measurement 17 was the difference between the labialesuperius and the stomion; this refers to the distance between the point where the upper lip truly begins, to the point where the upper and lower lips meet, or the thickness of the upper lip (see Figure (2)).

Measurement 19: labialesuperius to labialeinferius

Measurement 19 was the second of two measures found statistically significantly different ($p < .05$) for Age Group 3. Measurement 19 was the distance from the labialesuperius to the labialeinferius; this is the distance between where the upper lip truly begins to where the lower lip truly ends, or the thickness of the upper and lower lips combined (see Figure (2)). Significant differences could be due to a difference in BMI, differences in water retention, or a difference in facial expression between twins. Thinning of the lips also generally occurs as adults age, which could explain the difference in this dimension between twins of different age groups, similar to the finding for Measurement 17.

Results of the above analyses were compared to findings from the study conducted on subadult monozygotic twin facial similarity by Naini and Moss [7]. Naini and Moss [7] obtained their face data by taking 3 - dimensional facial scans of subadult monozygotic twins. This method may have allowed for more sensitive data analysis when compared to the present study's method of land marking 2 - dimensional digital face images from a database.

Although the images for the present study were standardized, there was the possibility of greater error, associated with placing the landmarks on faces, and then taking measurements when compared to taking a 3 - dimensional facial scan of an individual. Moreover, it is possible that the 2-D data be less sensitive to statistical analyses when compared to 3-D surface facial scans. It is also possible that the selected measures may not translate to the differences seen visually. This means that the human eye may be picking up on differences in facial features that are qualitatively different between twin sets and that the quantitative features (the measured dimensions) are not features adequately represent facial similarity or dissimilarity.

Table 7: Results of paired samples t-tests comparing Twin A to Twin B within a given twin set for all facial dimensions.

Age Group	Sample Size (Twin Sets)	Number of Twin Sets with Significant Differences in Facial Measures	Percentage of Twin Sets with Significant Differences in Facial Measures
1	17	7	41
2	25	9	36
3	23	10	44

Naini and Moss [7] compared 3-D facial surface shape-analysis scans among and between pairs of subadult (ages 6-18 years old) monozygotic twins. Their study using facial scans was conducted for two reasons: to see if facial scans supported inter landmark measurements taken between each twin within a twin set (similar to this study) and to compare areas of the face that differentiated monozygotic twin sets. Two scans were taken for each individual and then averaged together to avoid any error in intra - examiner reproducibility. Naini and Moss [7] found that the "greatest genetic determination of appearance seems to be the mid facial area between the lateral orbital rims and the nose." They also found that the lips, mouth, and cheeks are not very similar. This finding is consistent with findings from this study, which showed statistically significant differences in the lip region. This suggests that this area of the face is either dissimilar between monozygotic twins in general or it is easily distorted by a change in facial expression. Other extrinsic factors including BMI, use of makeup, water retention, etc., which can alter facial appearance, may help explain the statistically significant differences observed in the labiale (lip) region.

Analysis of t-tests comparing Twin A to Twin B in each twin set using all measures of facial dimensions

For the second set of paired samples t - tests, all of the facial dimensions for Twin A were compared to all of the dimensions for Twin B for all 65 twin sets as adult age increases. Twin A and Twin B represent two separate twins that belong to the same twin set. The goal was to determine if there is greater deviation in facial appearance due to age throughout the lifetime of adult twins. This was done by using paired samples t - tests; statistically significant differences would support the hypothesis that older adult twins would show more evidence of deviation in facial appearance when compared to young adult twins and especially when compared to the subadult monozygotic twins in the reference sample [7]. In Age Group 1, the youngest age group (18-27 years old), 7 out of 17 twin sets showed statistically significant differences ($p < .05$) between Twin A and Twin B in a given twin set (41%). In Age Group 2, middle-aged adults (37-51 years old), 9 out of 25 twin sets yielded statistically significant differences ($p < .05$) between Twin A and Twin B in a given twin set (36%). For Age Group 3, the oldest age group, 10 out of 23 twin sets showed statistically significant differences ($p < .05$) between Twin A and Twin B for a given twin set (44%). The findings for these t - tests are shown in Table (7). Table (8) shows the same information, but with the sample in greater detail with ages and sexes of twin sets listed.

The percent difference is roughly the same for all three age groups; there is no suggestion that twins' faces in older twin sets are more distinguishable than the younger twin sets. No patterns connecting a change in facial appearance to age could be established based on the given results of the paired sample t - tests. These test results reflected a difference in twins' facial appearance in general, regardless of age. These results, when compared to findings from Naini and Moss [7], seem to support the interpretation that epigenetic factors perhaps have a stronger influence on facial appearance at younger ages, during the processes of growth and development, whereas environmental factors seem more influential at older ages.

One of the main goals of this study was to identify the role that epigenetics may have on the facial appearance of adult twins' faces as a function of age. Based on the analyses it appears that epigenetics does not seem to have a measurable effect on face aging in adult identical twins. While epigenetics involves minute mutations that change the overall structure of DNA, they do not seem to have a major impact on facial appearance at least where 2-dimensional facial measurements are concerned as aging progresses in adult monozygotic twins. Epigenetics could play a minor role in facial appearance as a function of aging. However, epigenetic factors may only affect certain individuals in certain cases and may not be measurable in the same way in all people.

Figures (3-5) (with twin sets lettered a-l for ease in referencing) are examples of twin sets that do and do not show statistically significant differences in facial dimensions between Twin A and Twin B. As seen in the photographs, some of the images that resulted in statistically significant differences ($p < .05$) for the paired samples t - tests are of faces that look very similar to the human eye (Figure 3a,3b,4e,4f,5i,5j), while some of the images that did not show any statistically significant differences are of faces that look quite dissimilar to the human eye (Figure 3c,3d,4g,4h). Naini and Moss [7] suggest that genetic and environmental changes influence the shape of the face and changes in dimension between twins. This study suggests that epigenetic factors do not seem to have a discernable effect on 2-dimensional facial measurements in adult twin sets of various ages.

CONCLUSION

Paired sample t-tests were run to compare different facial dimensions among and between the three different age groups. Measurement 17 and Measurement 19 were found to be statistically significantly different for Age Group 3. Measurement 21 showed a statistically significant difference for Age Group 1 but not for Age Group 2 or Age Group 3. All three measurements that showed statistically significant differences were found in the labiale (lip) region of the face, which can be easily altered by facial expression and other extrinsic factors such as body mass index (BMI), water retention, and use of makeup.

The second set of paired sample t - tests compared all of the dimensions of Twin A to all of the dimensions of Twin B in a twin set, for all 65 twin sets. The percentage of statistically significantly different twin sets for all three age groups was roughly the same which implies that epigenetics does not have a major measurable effect on certain facial measures as adult monozygotic twins age. However, epigenetics could play a minor role in the differences in facial appearance between each twin from a given twin set; developing a method to detect this is key. Figures (4-6) help show that the human eye is still superior in terms of detecting facial similarities and dissimilarities.

The limitations to this study were centered upon the methods both in data collection and in analysis. Data collection was performed on 2-dimensional digital images from a database; it was not possible to obtain 3-dimensional facial scans of the same individuals. Manual placement of the landmarks on each individual twin facial image could have resulted in minor errors in the results. It is also likely that the facial measures

Table 8: t-test analyses of individual twin sets.

Twin Set	Age	Sex	Age Group	Statistically Significant Results (Divergence in Facial Appearance) in Twin A and Twin B from Paired Samples t-tests
1	18	F	1	No
2	18	M		No
3	18	F		No
4	18	M		Yes
5	18	F		No
6	19	F		Yes
7	19	M		Yes
8	19	F		No
9	20	M		No
10	21	F		Yes
11	22	M		Yes
12	23	F		No
13	24	M		No
14	24	F		Yes
15	26	F		No
16	26	F		No
17	27	F		Yes
18	37	F	2	No
19	37	F		No
20	38	F		No
21	38	M		No
22	39	F		Yes
23	41	F		No
24	41	F		No
25	41	F		Yes
26	41	F		No
27	42	F		No
28	42	F		Yes
29	42	F		No
30	44	F		No
31	45	F		No
32	46	F		Yes
33	47	F		No
34	47	M		Yes
35	47	F		Yes
36	48	F		No
37	49	F		Yes
38	49	F		No
39	49	F		No
40	50	F		Yes
41	51	M	2	Yes
42	51	M		No
43	54	F	3	Yes
44	54	F		Yes

45	55	M		No
46	55	F		No
47	55	F		Yes
48	56	F		No
49	56	F		No
50	56	F		No
51	60	F		No
52	61	F		No
53	62	F		No
54	63	F		Yes
55	65	F		No
56	66	F		Yes
57	67	F		No
58	69	F		No
59	69	F		No
60	72	M		No
61	72	F		Yes
62	74	F		Yes
63	76	M		Yes
64	77	F		Yes
65	78	F		Yes

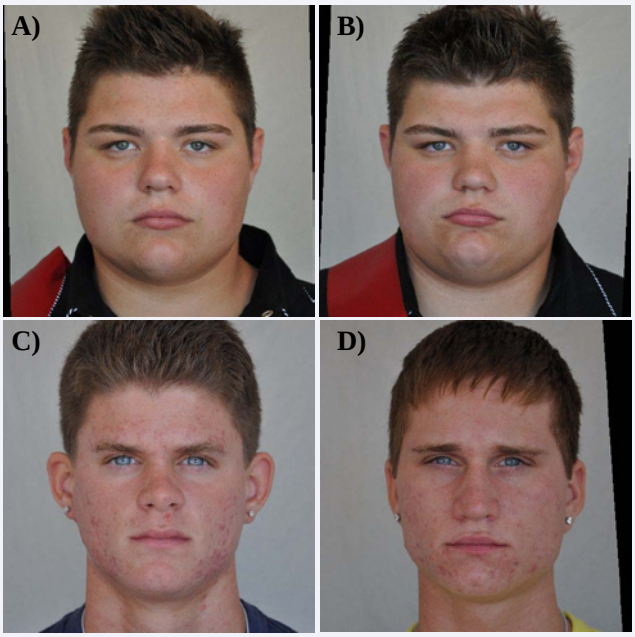

Figure 3 Age Group 1 Twin Sets (a-b, c-d) [9].

selected simply do not show differences that can be detected quantitatively something that human perception is better picking up on. Evidence from this study supports that computer automated facial recognition technologies benefit more from focusing on facial features that tend to remain constant, rather than those that change, with increasing adult age.

When combined with other biometrics, computer automated face recognition technologies work fairly well. However, by itself, as with any other biometric, there are limitations. Research in the forensic sciences geared toward biomertrics aims to synthezie and integrates the various methods available, such as fingerprinting, iris detection, voice and gait identification, and face recognition to improve security and accuracy in the authentication and verification of human identity. By understanding that epigenetics

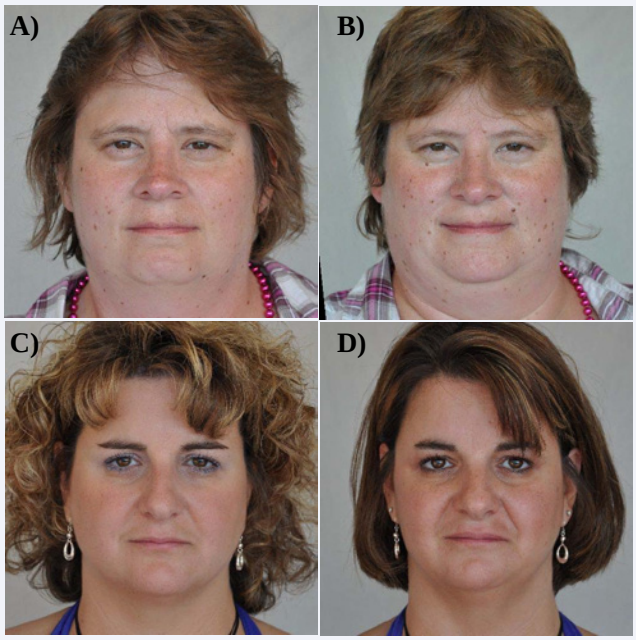

Figure 4 Age Group 2 Twin Sets (a-b, c-d) [9].

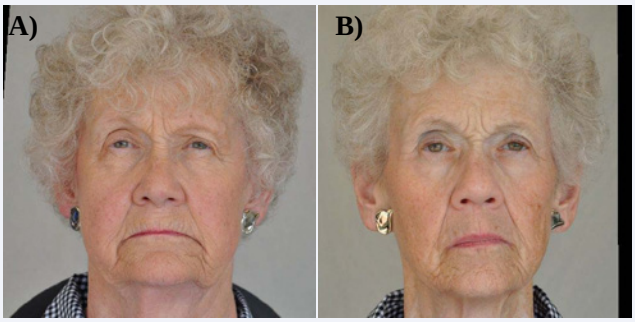

Figure 5 Age Group 3 Twin Sets (a-b) [9].

does not currently have a detectable measureable effect on adult face aging, new knowledge is brought to the forensic sciences that informs the next steps in research in this growing area.

REFERENCES

1. Albert AM, Ricanek K Jr, Patterson E. A review of the literature on the aging adult skull and face: Implications for forensic science research and applications. Forensic Sci Intl. 2007; 172: 1-9.
2. Guyuron B, Rowe DJ, Weinfeld AB, Eshraghi Y, Fathi A, Iamphongsai S. Factors contributing to the facial aging of identical twins. Plast Reconstr Surg. 2009; 123: 1321-1331.
3. Tammen SA, Friso S, Choi SW. Epigenetics: The link between nature and nurture. Mol Aspects Med. 2013; 34: 753-764.
4. Singh SM, Murphy B, O'Reilly R. Epigenetic contributors to the discordance of monozygotic twins. Clin Genet. 2002; 62: 97-103.
5. Fraga M, Ballestar E, Paz M, Ropero S, Setien F, Ballestar M, et al. Epigenetic differences arise during the lifetime of monozygotic twins. Proc Natl Acad Sci U S A. 2005; 102: 10604-10609.
6. PetronisA, Gottesman II, Kan P, Kennedy J, Basile V, Paterson AD, et al. Monozygotic Twins Exhibit Numerous Epigenetic Differences: Clues to Twin Discordance? Schizophr Bull. 2003; 29: 169-178.
7. Naini FB, Moss JP. Three-dimensional assessment of the relative contribution of genetics and environment to various facial parameters with the twin method. Am J Orthod Dentofacial Orthop. 2004; 126: 655-665.
8. Ngaladel. The Face Sketch. Digital image. DeviantART. 2012; (last accessed February 18, 2016).
9. Phillips PJ, Flynn P, Bower K, VorderBruegge R, Grother P, Quinn G, et al. Distinguishing identical twins by face recognition.
10. Barbour B, Ricanek K. An interactive tool for extremely dense landmarking of faces. Proceedings of the 1st International Workshop on Visual Interfaces for Ground Truth Collection. 2012; 13: 1-5.

Cite this article

Albert AM, Lloyd CC (2016) Human Variation in Face Aging in Adult Monozygotic Twins: Biometric Implications for the Forensic Sciences. Ann Forensic Res Anal 3(1): 1027.