Identity Transfer and Identity Restoration in Face Transplantation.

Ajay Modgil M.D.

Abstract:

BACKGROUND: Facial allotransplantation is fast becoming a reconstructive option for severely disfigured individuals. Only nine face transplants have been done around the world but experimental nature of the procedure itself is a limiting factor to achieve its full potential as a therapeutic option. Face transplant will be ethical only when it addresses the patient's identity concerns. There exist no such studies that quantify and predict identity changes following change in geometry of underlying facial skeleton.

METHODS: Using software (Mimics version 14.0, Materialise, Michigan, USA), three dimensional facial models were developed from the CT scan images of four identical and one non-identical twin pairs. Three dimensional coordinate values of selected landmark locations were measured (Surgicase, Materialise, Michigan, US) and a morphometric method was applied to quantify identity differences between them based upon cranial base anatomy. Identity parameters were drawn on a diagrammatic chart that depicted the bio-physical identity range. Using software (Mimics version 14.0), face transplantation simulation was done involving most of the nasal bone, maxilla and zygoma. Morphological parameters of resulting new identity were drawn on diagrammatic chart and if they fell within the chart, face transplantation resulted in identity transfer.

RESULTS: Identity transfer was distinctly noticed among few subjects and resulting identity changes were quantified.

CONCLUSION: This study proves wrong the common belief that no identity transfer occurs in face transplantation and this information can be objectively used in the informed consent process of face transplantation.

Introduction:

The first radical facial surgery which restored facial appearance was done in India in 1994, when Dr. Thomas, a micro-surgeon, replanted the entire face of a nine-year-old girl who had lost her face and scalp in a threshing machine accident[1]. This might have inspired plastic surgeons the world over to wonder if new faces could be transplanted onto severely disfigured patients. After much ethical debate, first human face transplantation was done in Lyon, France, in 2005[2]. Face transplantation will be considered ethical only when informed consent process address the identity concerns to potential recipients and donors[3].

Few authors have investigated the identity issues of face transplantation. Siemionow et al[4] found that final appearance of a recipient is a mixture of features of both recipient and donor. Baccarani et al[5] concluded that recipient's appearance depends upon bony framework of the underlying cranium. Pomahac et al[6] found negligible appearance transfer to the recipients from donors.

However, no study quantifies and predicts identity changes with the altered geometry of underlying bony framework. Only nine face transplants have been done around the world[7] and experimental nature of face transplantation itself is a limiting factor in decision-making with regard to donation and receipt of facial grafts. A method is urgently required that not only predicts the identity changes, but also can be used as a scientific tool to educate potential face transplant recipients and donors.

The aim of the study was to:

1. Quantify and predict identity changes pre-face transplantation.

2. Develop a morphometric method to predict identity changes relative to recipient's family facial phenotype.

Methods and materials:

Subjects:

Five twins—aged between 20 and 33 years (mean age 23)—were selected on the basis of lack of any cranio-facial trauma, surgery, congenital deformity, or unknown lesion and the fact that they were not being treated for any medical deformity, underwent CT scan. All twins were living together for most of their life and were of north Indian descent. Four twin pairs were monozygotic and one twin pair was dizygotic as was determined at the time of their birth on the basis of anthropometric and serologic methods. They were explained in details about purpose and nature of study in their native language before informed consent was taken.

Imaging and software:

CT (multi-slice) images with a high-resolution bone algorithm (512 x 512 matrix, 120 KV, and 200 mA), were taken using CT scanner (Siemens, Germany) and image covered the area from vertex to sub-mandibular region of cranio-facial complex. Acquired CT slice data were imported to workstation (Windows 7, Intel i5-650 dual-core processor, 512MB NVIDIA GeForce graphics card) and reconstructed in three dimensions. A life size facial model was developed using segmentation and volume rendering techniques (Mimics version 14.0, Materialise, Michigan, USA). Hard and soft tissues were separated by threshold-based segmentation, based on differences in their permeability to x-rays.

Three dimensional (3D) morphometric analyses:

Software (Surgicase, Materialise, Michigan, US) allowed creating a template of landmark locations (Table 1) and measurements were recorded between them. 3D spatial coordinate system was defined by using four landmarks: Nasion, Basion, Prosthion and Sella. The y-z plane passed through Nasion, Basion and Prosthion in midline. The x-y plane was perpendicular to y-z plane, passing through Nasion and Sella while z-x plane was perpendicular to y-z and x-y planes, passing through Basion.

The X-axis was determined roughly parallel to right-left direction of subject's maxillofacial skeleton. Y-axis and Z-axis corresponded to anterior-posterior and inferior- superior directions, respectively. 3D coordinate values (dx, dy, dz) were calculated for landmarks Bc, Pr and Mx with origin (0, 0, 0) set at Ba. For Pr, only Y and Z axis values

Table 1. Landmarks used in this study

Landmark	Abbreviation	Definition
Nasion	Na	Most posterior point on curvature between frontal bone and nasal bone in the mid sagittal plane
Basion	Ba	Most anterior point of foramen magnum
Sella	S	Geometric center of the pituitary fossa
Buccale	Bc	Most prominent point on external surface of each zygomatic arch, where arch turns medially
Maxillare process	Mx	Point of maximum concavity on contour of maxilla directly below the lower contour of maxillozygomatic
Prosthion	Pr	Point of maxillary alveolar process between left and right maxillary incisors
Menton	Me	lowest border of the mid-mandibular suture
Pogonion	Pg	Most anterior midpoint of symphysis of mandible
Point B	B	Most posterior point of bony curvature of mandible above Pg
Mid face angle	Pr-Mx-Bc	Measures the convexity of mid face
Chin prominence	C.P.	Perpendicular distance from the Pg to B-Me line
Zygion	Zp	Most lateral point on the outline of each zygomatic arch
Face index	F.I.	(Na-Me distance)/ (distance between right and left Zp) 100%.

While for bilateral andmarks, x-axis (horizontal difference between two landmarks), Y-axis and Z-axis co-ordinate values (average of right and left side values) were measured (Fig 1). Displacement vector was calculated as difference between 3D coordinate values of a twin pair (T1, T2) and was named as Identity index for that particular landmark location (Fig 2).

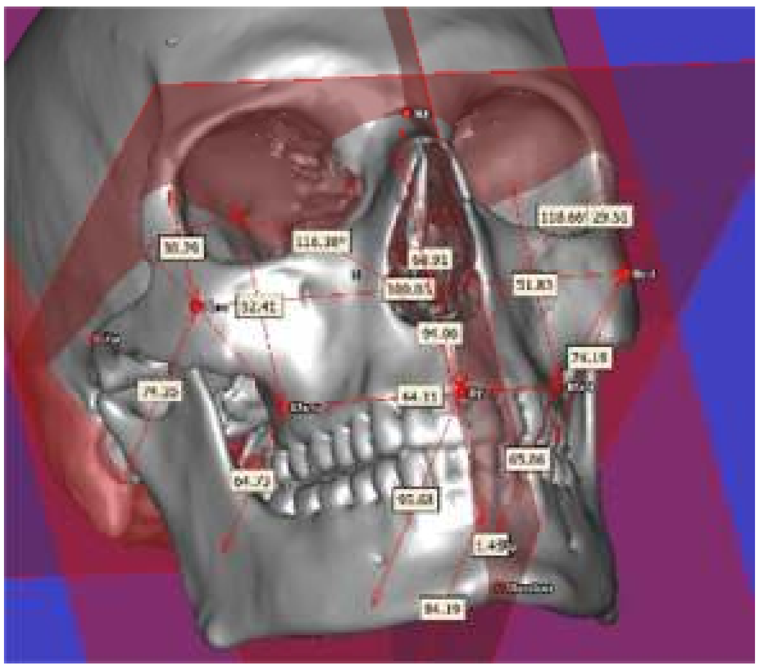


Figure 1. Landmark locations and their 3D measurements relative to set planes.

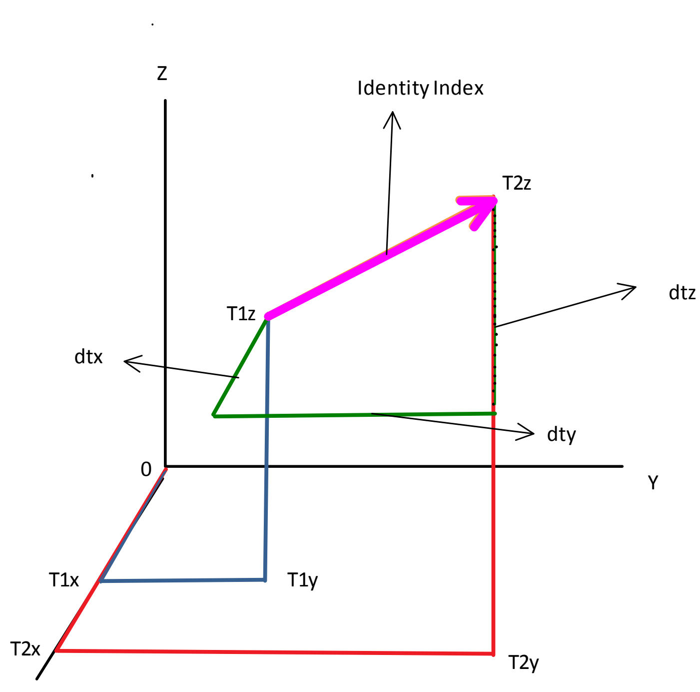


Figure 2. Identity Index was calculated as displacement vector (difference between three dimensional coordinates (T1x-, T1y-, T1z- and T2x-, T2y-, T2z-) of particular landmark location of a twin pair, T1 and T2).

Identity index = $\surd\, d\,(T1x-T2x)^2 + d\,(T1y-T2y)^2 + d\,(T1z-T2z)^2$

Mean and standard deviation values of identity indices (mm) and chin protuberance difference (mm) of identical twins were drawn on a diagrammatic chart that indicated the bio-physical identity range (Fig 3).

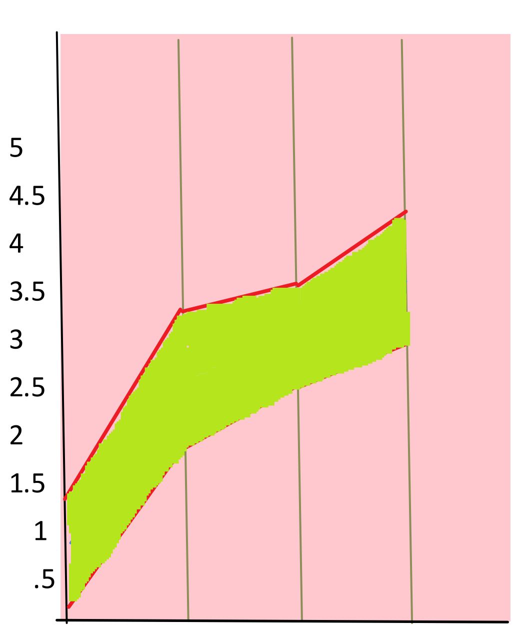


Figure 3. Diagrammatic chart indicates bio-physical identity range (green zone) of landmark locations. Blue line in the middle indicates mean values of identity indices (mm) while red lines indicate values of one standard deviation on either side.

Family morphometric analyses:

It has three parts.

1) Four subjects (Fn, n=1-4) were randomly chosen as single family unit excluding recipient, and mean values of 3D coordinates (Fx, Fy, Fz) at set landmark locations defined shape of family facial phenotype (F).

2) Displacement vector was calculated as difference between 3D coordinate values at set landmark location of individual family member and corresponding mean family values; and was called family identity index for that landmark.

Family Identity index = $\sqrt{d (Fnx-Fx)^2 + d (Fny-Fy)^2 + d (Fnz-Fz)^2}$

3) Mean and standard deviation values of identity indices (mm) of a particular landmark and nose length (mm) of all family members were indicated on a diagrammatic chart that depicted the family identity pool (Fig 4).

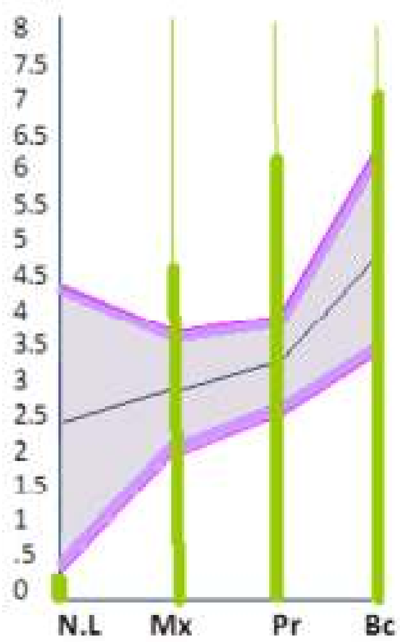


Figure. 4 A diagrammatic chart indicates the family identity pool. Family identity indices (mm) of recipient were plotted to find if recipient's new identity became part of family phenotype.

Face transplantation and identity changes prediction:

Using point registration (Mimics version 14.0) at infraorbital margin, nasion and prosthion on facial skeleton, recipient and donor's transparent facial images were superimposed; donor graft in the mid face area was cut out using a cutting plane that included lower half of nasal bone, whole maxilla including most of the hard palate and zygoma and was transplanted onto recipient's face (Fig 5). Four subjects received facial graft from two donors that resulted in eight face transplants. Identity indices were calculated for defined landmark locations of recipient's changed identity (Fig 6) and native identity and plotted on bio-physical identity range chart. If they fell within identity range, it depicted identity transfer: otherwise, face transplantation resulted in a new identity.

Additionally, a donor compatible with family phenotype was chosen and recipient's family identity indices were plotted on chart. If they fell within identity pool, recipient's new identity became part of family phenotype (Fig 4).

Statistical analysis:

All processes were performed by one author (A.M). Errors in landmark localization were evaluated by comparing differences between 3D coordinates, angular measurements, and linear measurements of original and repeated examinations of 10 subjects during a 2-week time interval. Method error was calculated as SE $=\sqrt{(\Sigma d^2/2n)}$, where d is the difference between double measurements and n is the number of paired double measurements.

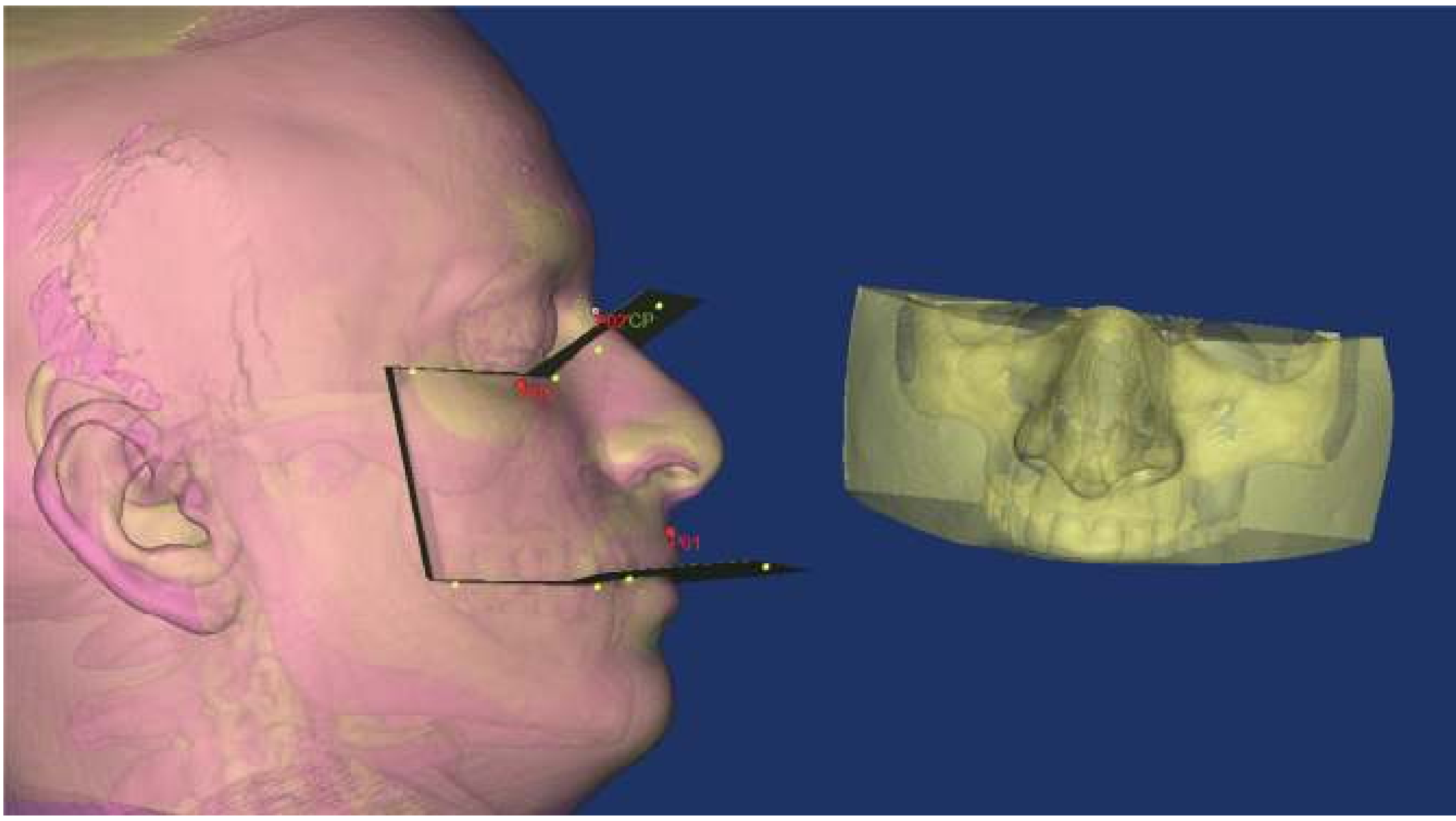


Figure 5. Recipient and donor's images were super-imposed and using cutting plane (CP), appropriate sized graft was cut out.

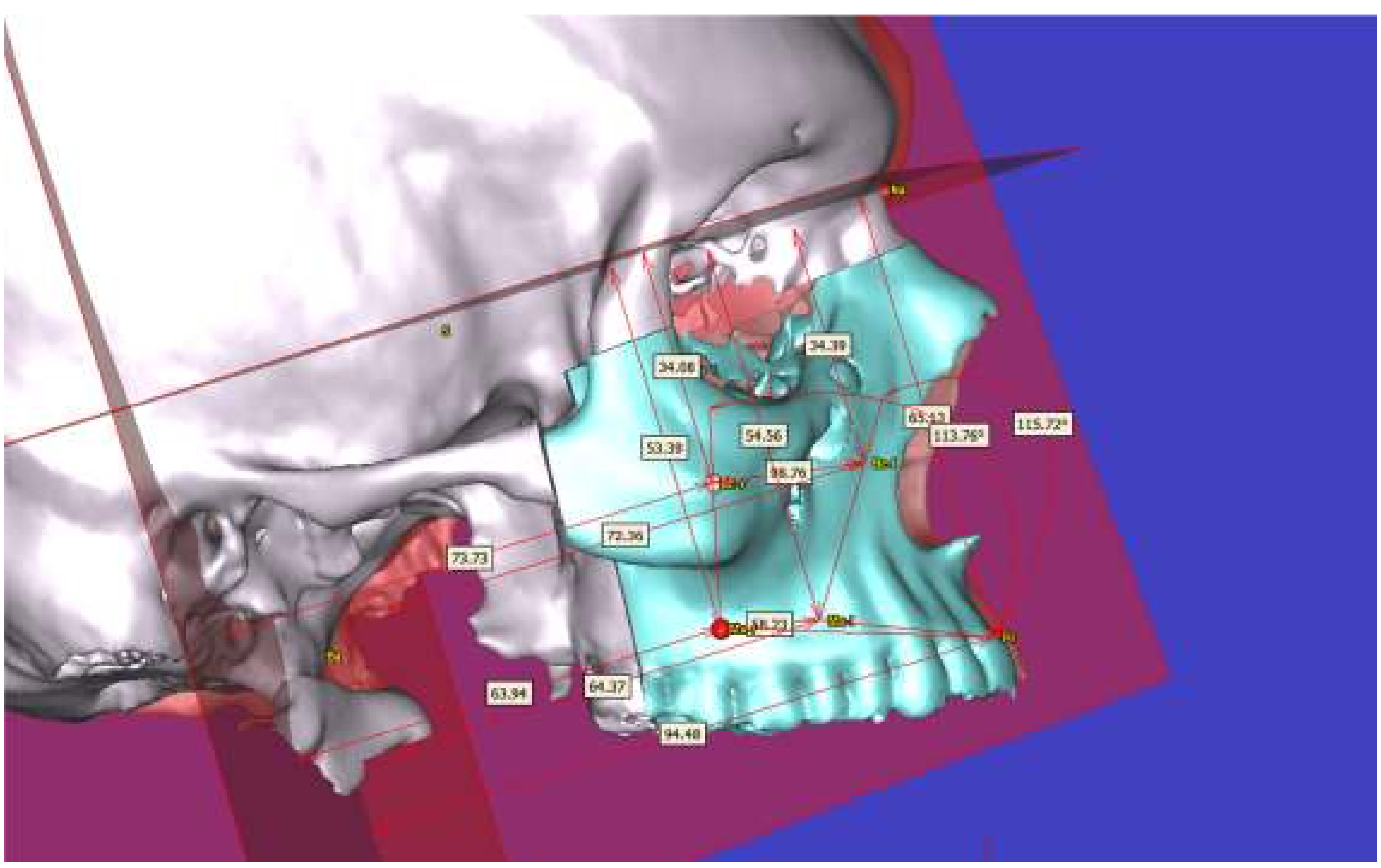


Figure 6. 3D measurements of recipient's cranio-facial complex after face transplantation.

Results:

Table 2 show 3D coordinate values of landmark locations, identity indices (identical twins only), and table 3 show 3D coordinates values and identity indices between new identity resulting from face transplant and native identity while table 4 show values of shape of family phenotype and family identity pool. Measurement errors of intra-observer precision were 1.1 mm, 1.0 mm, 1.3 mm for the x, y, and z coordinates, respectively; it was 1.128 for angular measurements and 1.4 mm for the linear measurements. No statistical difference was detected between original and repeated measurements.

Table 2. Values (mm) of x-, y-, z-, coordinate of landmark locations, Identity Indices and other morphological parameters.

		T1A	T1B	T2A	T2B	T3A	T3B	T4A	T4B	Mean	SD	T5A*	T5B*
Bc-X		102.93	105.37	97.8	98.27	110.31	109.29	100.03	97.14			98.51	100.83
	dx	2.44		0.47		1.02		2.89				2.32	
Bc-y		69.3	67.18	73.72	72.25	66.97	64.92	74.3	75.45			73.71	71.49
	dy	2.12		1.47		2.05		1.15				2.22	
Bc-z		29.6	28.62	29.32	28.99	27.96	27.03	29.69	29.75			32.15	35.59
	dz	0.98		0.33		0.93		0.06				3.44	
I.I		3.33		1.57		2.25		3.10		2.6	0.8		
Mx-X		58.9	59.04	61.01	60.75	61.03	59.57	64.11	62.06			58.33	62.02
	dx	0.14		0.26		1.46		2.05				3.69	
Mx-Y		64.24	60.46	61.38	62.49	62.95	60.59	64.76	63.96			63.7	65.35
	dy	3.78		1.11		2.36		0.8				1.65	
Mx-z		47.29	48.52	52.68	54.87	52.76	51.2	51.84	49.71			51.58	51.81
	dz	1.23		2.19		1.56		2.13				0.23	
I.I		3.97		2.45		3.18		3.06		3.2	0.6		
Pr-y		94.8	92.55	95.49	96.98	91.44	89.54	95.41	92.44			94.26	98.03
	dy	2.25		1.49		1.9		2.97				3.87	
Pr-z		57.74	60.59	66.43	64.35	61.6	62.65	68.86	70.06			62.53	61.68
	dz	2.85		2.08		1.05		1.2				0.95	
I.I		3.63		2.55		2.17		3.2		2.9	0.7		
C.P		3.75	2.2	3.1	2.84	2.6	2.9	1.45	2.97			3.65	5.51
		1.55		0.26		0.3		1.52		0.9	0.7	1.96	
A°		122.78 °	121.32 °	107.42 °	107.70 °	124.78 °	121.55 °	117.52 °	114.51 °			112.40 °	117.79 °
BMI		19.9	18.6	25.2	25.3	17.1	19.9	22.3	23.7			23.3	21.5
F.I		85	86	89	86	85	83	80	90			89	84
Max. µ		SL	SL	SL	SL	SL	SL	Tri.	Tri.			SL	SL
N.L		50.96	46.37	48.94	49.02	47.86	47.67	51.54	53.03			41.51	47.03

S.D: standard deviation, I.I: Identity Indices, C.P: chin protuberance, A°: mid face angle, BMI: body mass index, F.I: face index.

* Non-identical twins. µ: Maxillary shape. SL: Semi-lunar, Tri: Triangular, N.L: Nose length.

Table 3. Values (mm) of x-, y-, z-, coordinate of landmark locations, Identity Indices of transplanted faces -- (FT n, n=1-8).

		FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8
		(T5B-t4b †)	(T5A- t4b †)	(T1A- t4b †)	(T4A- t4b †)	(T5B-t2a †)	(T5A- t2a †)	(T1A- t2a †)	(T4A- t2a †)
Bc-X		97.14	97.14	97.14	97.14	97.8	97.8	97.8	97.8
	dx‡	3.69	1.37	5.79	2.89	3.03	0.71	5.13	2.23
Bc-y		74.22	72.72	71.28	74.81	75.08	73.63	69.2	77.65
	dy‡	2.73	0.99	1.98	0.51	3.59	0.08	0.1	3.35
Bc-z		32.79	32.2	31.71	30.83	29.18	29.84	27.75	26.29
	dz‡	2.8	0.05	2.11	1.14	6.41	2.31	1.85	3.4
I.I		5.37	1.43	6.47	3.3	7.49	2.41	5.45	5.26
Mx-X		62.06	62.06	62.06	62.06	61.01	61.01	61.01	61.01
	dx‡	0.04	3.73	3.16	2.05	0.01	2.68	2.11	3.1
Mx-Y		67.19	63.94	64.14	67.05	66.16	63.38	59.91	65.64
	dy‡	1.74	0.24	0.1	2.29	0.81	0.32	4.33	0.88
Mx-z		54.8	52.27	52.16	51.56	54.3	52.46	52.18	50.14
	dz‡	2.99	0.69	4.87	0.28	2.49	0.88	4.89	1.7
I.I		3.45	3.79	5.88	3.07	2.61	2.83	7	3.62
Pr-y		92.28	95.59	93.57	96.07	99	95.62	92.3	97.4
	dy‡	5.85	1.33	1.23	0.66	0.97	1.36	2.5	1.99
Pr-z		66.51	64.31	66.2	65.97	64.69	64.57	63.88	63.47
	dz‡	4.83	2.18	8.46	2.89	3.01	2.04	6.14	5.39
I.I		7.58	2.5	8.54	2.96	3.15	2.41	6.62	5.74
C.P £		5.51	3.65	3.75	1.45	5.51	3.65	3.75	1.45
	Δ	1.54	1.68	0.78	1.52	2.41	0.55	0.65	1.65

†: Bold and small letters indicate recipient and donor respectively, ‡: coordinate value difference between recipient's new and native identity, I.I.: Identity index, £: chin protuberance, Δ: C.P. difference between donor and recipient.

Table 4. Values (mm) of x-, y-, z-, coordinate of landmark locations, Identity Indices and other parameters used in family morphometric study.

		F1	F2	F3	F4	Mean	SD	FP‡	FT†	D±
Bc-X		102.93	105.37	97.8	98.27			101.1	100.03	100.03
	dx®	2.9	5.07	3.5	2.03				0.98	
Bc-y		69.3	67.18	73.72	72.25			70.6	64.92	74.3
	dy®	0.76	2.88	3.66	2.19				5.68	
Bc-z		29.6	28.62	29.32	28.99			29.1	27.03	29.69
	dz®	0.5	0.48	0.22	0.11				2.07	
I.I		3.03	5.85	5.66	2.96	4.4	1.6		6.12	
Mx-X		58.9	59.04	61.01	60.75			59.9	64.11	64.11
	dx®	1	0.86	1.11	0.85				4.21	
Mx-Y		64.24	60.46	61.38	62.49			62.1	61.03	64.76
	dy®	0.14	1.64	0.72	0.39				1.07	
Mx-z		47.29	48.52	52.68	54.87			50.8	51.2	51.84
	dz®	3.51	2.28	1.88	4.07				1.4	
I.I		2.13	2.8	2.29	4.1	2.8	0.9		4.62	
Pr-y		94.8	92.55	95.49	96.98			95	90.02	95.41
	dx®	0.2	2.45	0.49	1.98				4.98	
Pr-z		57.74	62.59	66.43	63.35			62.5	66.02	68.86
	dy®	2.76	0.09	3.93	0.85				3.52	
I.I		2.76	2.45	3.95	2.15	2.8	0.8		6.09	
NL		50.56	45.37	53.03	51.94			50.2	49.75	49.8
		0.36	4.83	2.83	1.74	2.4	1.9		0.45	
A		122.78 °	121.32 °	107.42 °	107.70 °			114.8 °	117.52 °	117.52 °

SD: standard deviation, ‡: shape of family phenotype, †: recipient's new identity, ±: donor, ®: coordinate value difference between new and native identity, I.I: Identity index, NL: nose length, A: mid-face angle.

Discussion:

To study variations among human faces, it is necessary to study the structures that compose it—skull characteristics, musculature, and associated soft tissue. The mimetic musculature is stretched across facial skeleton like a mask and to a great extent; any change in form of facial bones causes variations in facial appearance[8]. Face transplant is a type of composite tissue transplantation that replaces the missing anatomical structures with identical ones and differs from other organ transplantation in degree hence, composition of its anatomical elements. Accordingly, face transplantation can be divided into two main categories: (1) myocutaneous: contain only soft tissues, (2) osteo-myocutaneous: ingrain hard tissues as well. Cadaveric studies show how recipient's final appearance will be a mixture of features from both the recipient and donor. Moreover, recipient's bony framework defines the new appearance along with external features of donor's graft, such as nose length[4, 5]. That is true for myocutaneous type of face transplant. But effects of change in underlying facial skeletal geometry on recipients' appearance in osteomyocutaneous transplants have not yet been explored.

It is important to know the fundamentals of shape perception in three dimensions to understand identity variations of human face. Perception of shape depends upon viewing direction, distance, and illumination. Shapes look different in three dimensions depending upon how much light is reflected on their surface and illumination of adjacent environment[9]. If we assume an object of particular size that is made up of various small components, change in size and contours of any one component will not only reflect different amount of light but will also change the illumination of adjacent optical environment. Thus, object as a whole entity will be perceived different from its original shape. Similarly, human facial skeleton is made up of components whose individual size and shape is genetically predetermined but their spatial arrangement is influenced by environmental factors[11, 12] and together, they lend human face a unique identity.

A twin model seems to be best fit to address the identity issues of face transplantation. A bio-physical limit of geometric variations seems to exist in craniofacial complex of twins that forms two different but identical appearances. I hypothesize that craniofacial complex has three different optical environments that are contained by different size and contours of its skeletal components and overlying soft tissues mask them. These three environments are: inner, middle, and outer. Maxilla forms inner optical environment—and is central to human identity. It not only supports the nose and lip but also, there exist varied eminences, curves, and angles within its small surface, along with overlying soft tissues, contribute to unique facial appearance. Its immediate outer boundaries form middle optical environment that is marked by landmarks buccal, prosthion, and maxillare. Boundaries of outermost optical environment are ill defined and depend upon face index, body mass index, and chin characteristics (Table.4).

Inner optical environment (Central to facial identity)	1. Nose characteristics- a) Nose length, b) Nose shape. 2. Maxillary shape. 3. Mid-face angle-measures convexity of face.
Middle optical environment (Geometric bridge between outer and inner environments)	1. Buccal (Bc) - Signify malar eminences. 2. Maxillare (Mx) - Signifies mid-face width. 3. Prosthion (Pr) - Signifies length of mid-face.
Outer optical environment (Defines overall shape of cranio-facial complex)	1. Face Index (F.I.) - Defines contours of cranio-facial complex. 2. Chin characteristics - a) chin protuberance, b) chin shape. 3. Body Mass Index (B.M.I) – Affects thickness of facial mask hence, overall shape of cranio-facial complex.

Table.4. Classification of respective optical environments.

Contours of a bony segment are a true expression of its total morphological configuration[13], while geometric morphometric is a structured approach to analyze landmarks for shape variations[14]. Moreover, variations in facial morphology correspond to cranial base, acting as bridge between neuro-cranium and facial cranium; thus, any change in cranial base configuration is reflected on the face[15]. Reference planes in this study were set in a way that measured the physical dimensions of contours of facial bones based on cranial base anatomy. Displacement vector was calculated for the difference between three dimensional coordinates of a particular landmark location of same twin individuals that was called Identity index. Identity indices defined the limit of physical variations in size of middle optical environment with in which two different individuals are perceived identical.

To study a shape, one needs a constant stimulus that illuminates it[10]. If size and contours of components in the immediate optical environment of an object are kept constant, its shape can be distinctly appreciated and shape will be perceived different with any change in the environment (Fig 7). If size of outer and middle optical environments is kept constant, any change in the inner environment will be distinct. Thus, if geometry of middle environments of recipients and donors lies within range of identity indices, donor's face will be distinctly appreciated when transplanted on the recipient's face—and recipient's appearance will closely resemble the donor. Additionally, if a donor's nose characteristics and maxillary shape is same, recipient’s native identity will be nearly restored. But if they are different, a donor’s identity will be distinctly noticed on a recipient's face. This explains the phenomenon of identity transfer in face transplantation. Same stands true in myocutaneous type of face transplant if cranio-facial characteristics of donor and recipient are same; donor’s myocutaneous facial mask will resume its native identity on recipient’s facial skeleton. It proves wrong the common belief that no identity transfer occurs in face transplant patients[16, 17]. Nonetheless, if there is mismatch between outer and middle optical environments of recipient and donor, when transplanted, donor graft will optically interact with newly changed environment and whole craniofacial complex will be perceived as a new identity (Fig 8).

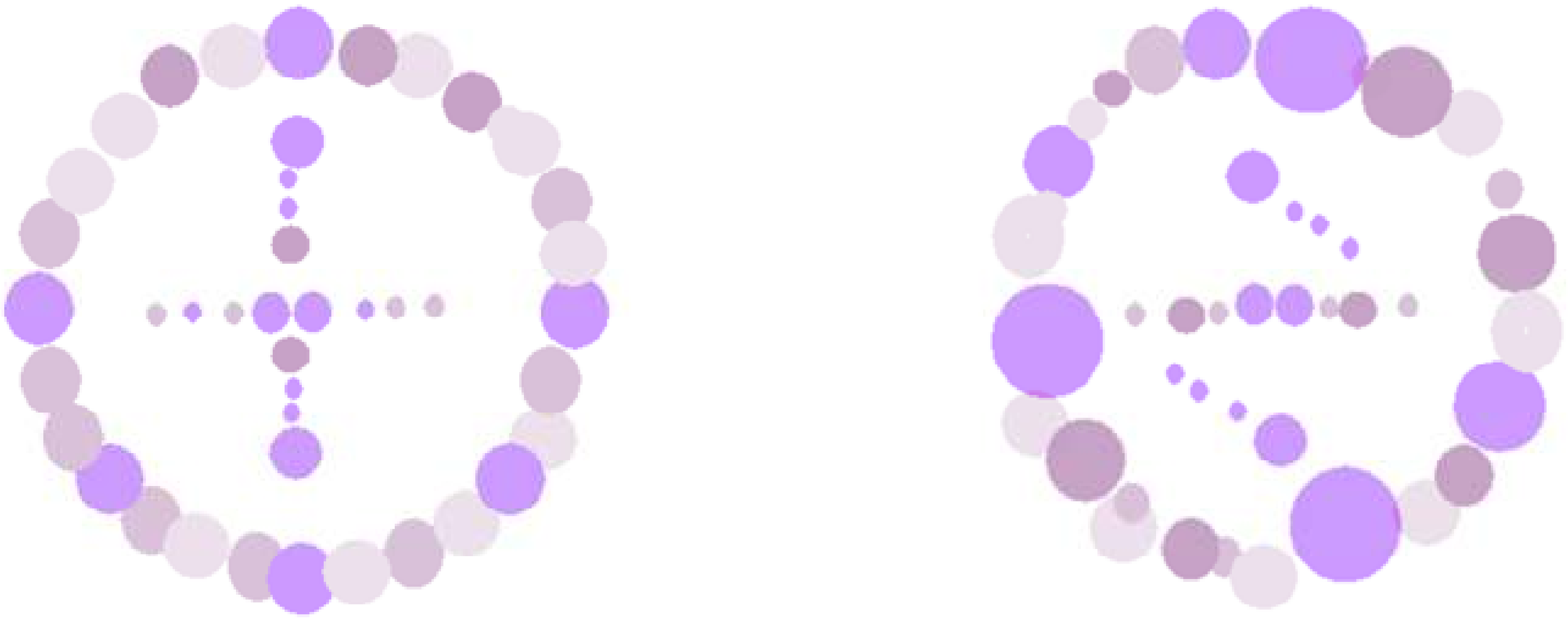


Figure 7. Inner environment of an object (A) will interact optically with the changed outer environment and hence, will be perceived different (B), even with no change in configuration of its morphology.

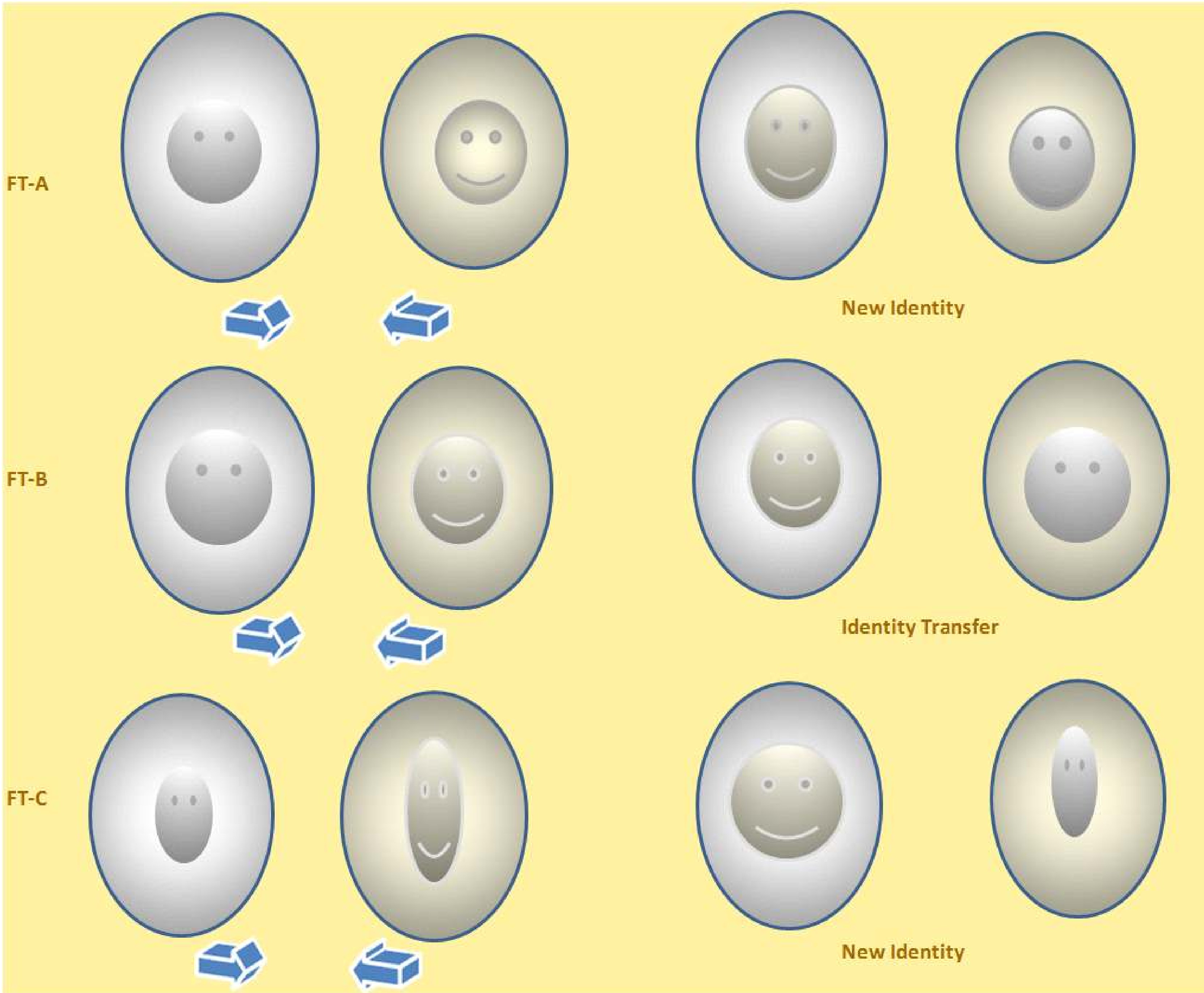


Figure 7. A schematic chart shows cross face transplantation between two subjects of different morphological configurations. Large circle represents size of outer optical environment while small circle depicts size and morphology of middle and inner optical environments, respectively. Identity transfer occurs (FT-B) when outer and middle environments are compatible in shape and size; otherwise, it results in new identity.

Identity transfer can be clearly seen in FT-2 and FT-6 (Fig 9, 10) since the size of middle optical environments is in identity range. Morphological incompatible recipient and donor (FT-3, FT-7) will result in new identity. Boundaries of outer optical environment will play important initial role in determining if face transplantation will result in identity transfer. Donor's facial graft will retain its native identity only when recipient's parameters of outer optical environment match with a donor's. Face index indicates the overall shape of craniofacial complex and average face index ranges from 85% to 89.99 %.[18] In FT-4, recipient and donor are identical twins but their face index is out of normal range (Table 2),(also see Fig.13). Parameters of their middle optical environment are in identity range and it is noticed that recipient's identity has been nearly restored moreover; recipient resembles the donor up to some extent. Mandibular chin has considerable effect in determining facial appearance[19] and facial graft will look same only when recipient's chin shape characteristics are compatible with the donor. In diagrammatic charts (Fig 11, 12), C.P. is chin protuberance difference between donor and recipient. Effects of chin shape on identity transfer can be clearly seen in FT-1, FT-2, FT-5 and FT-6. Higher BMI will not only alter the face index but will also affect optical perception of inner environments and hence, any possible identity changes.

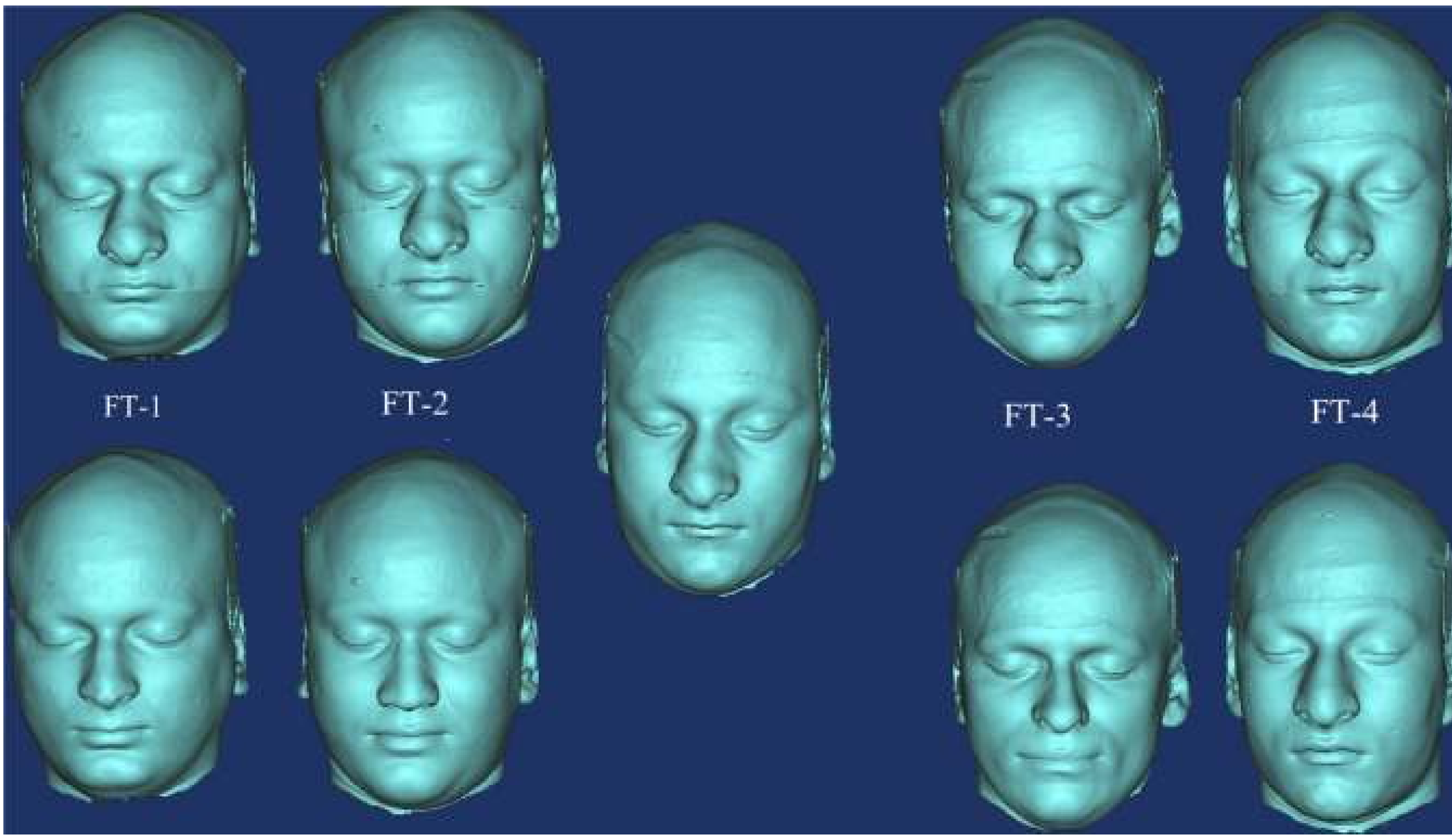
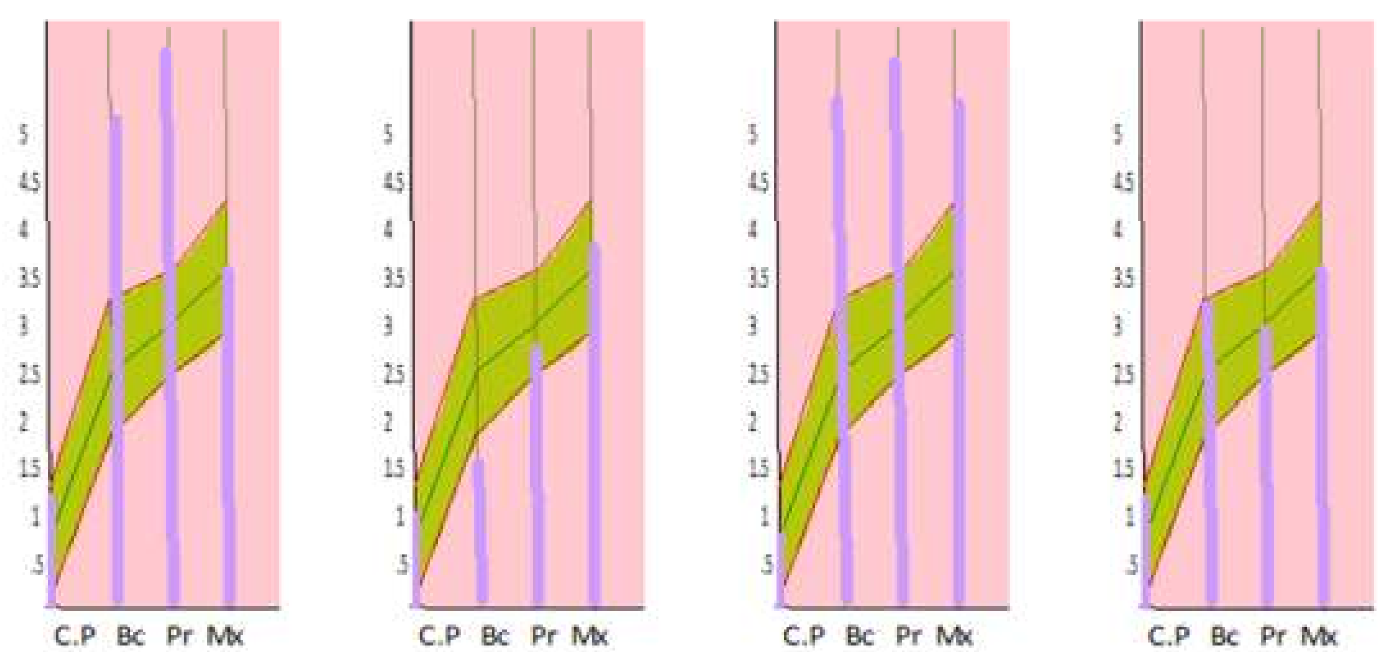


Figure 9. Representative of corresponding new facial images (top) of recipients (bottom) resulting from face transplantation. Donor is shown in the center.



A6M6 A9M5 A6M0 A8M10

FT-1 FT-2 FT-3 FT-4

Figure. 12. Identity indices (mm) of recipients plotted on bio-physical identity chart indicating if face transplantation resulted in identity transfer. Also shown are the identity scores of respective face transplantations.

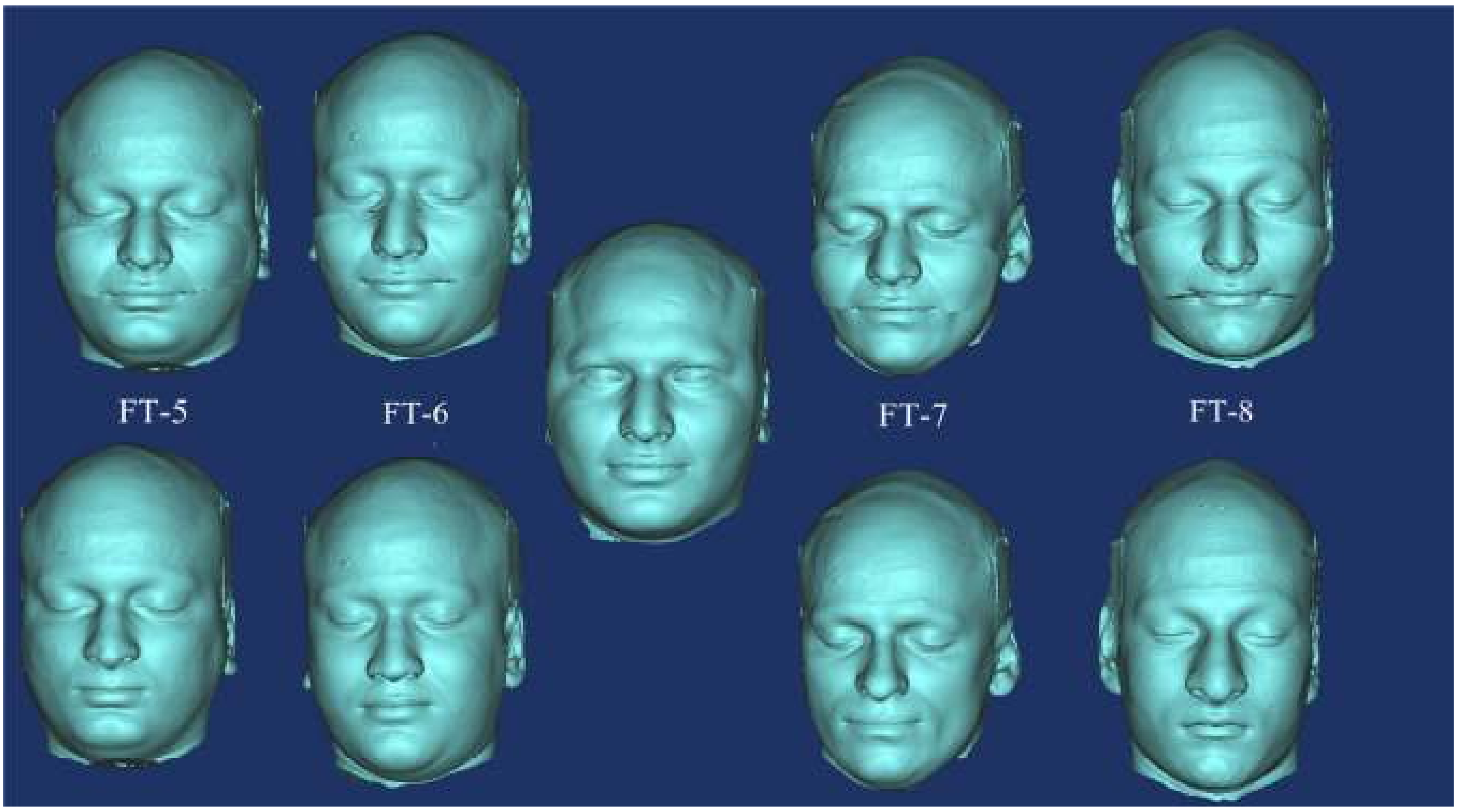


Figure 11. Representative of corresponding new facial identity (top) of recipients (bottom) resulting from face transplantation. Donor is shown in the center.

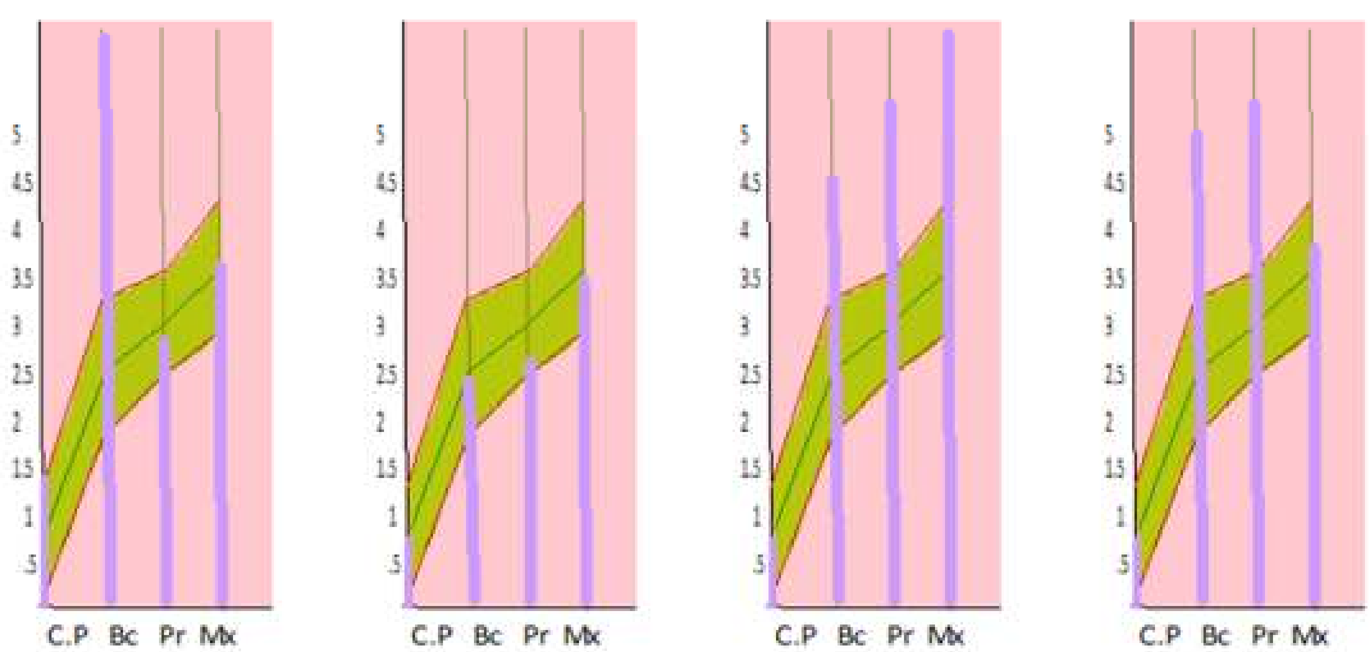


Figure 12 Identity indices (mm) of recipients plotted on bio-physical identity chart indicating if face transplantation resulted in identity transfer.

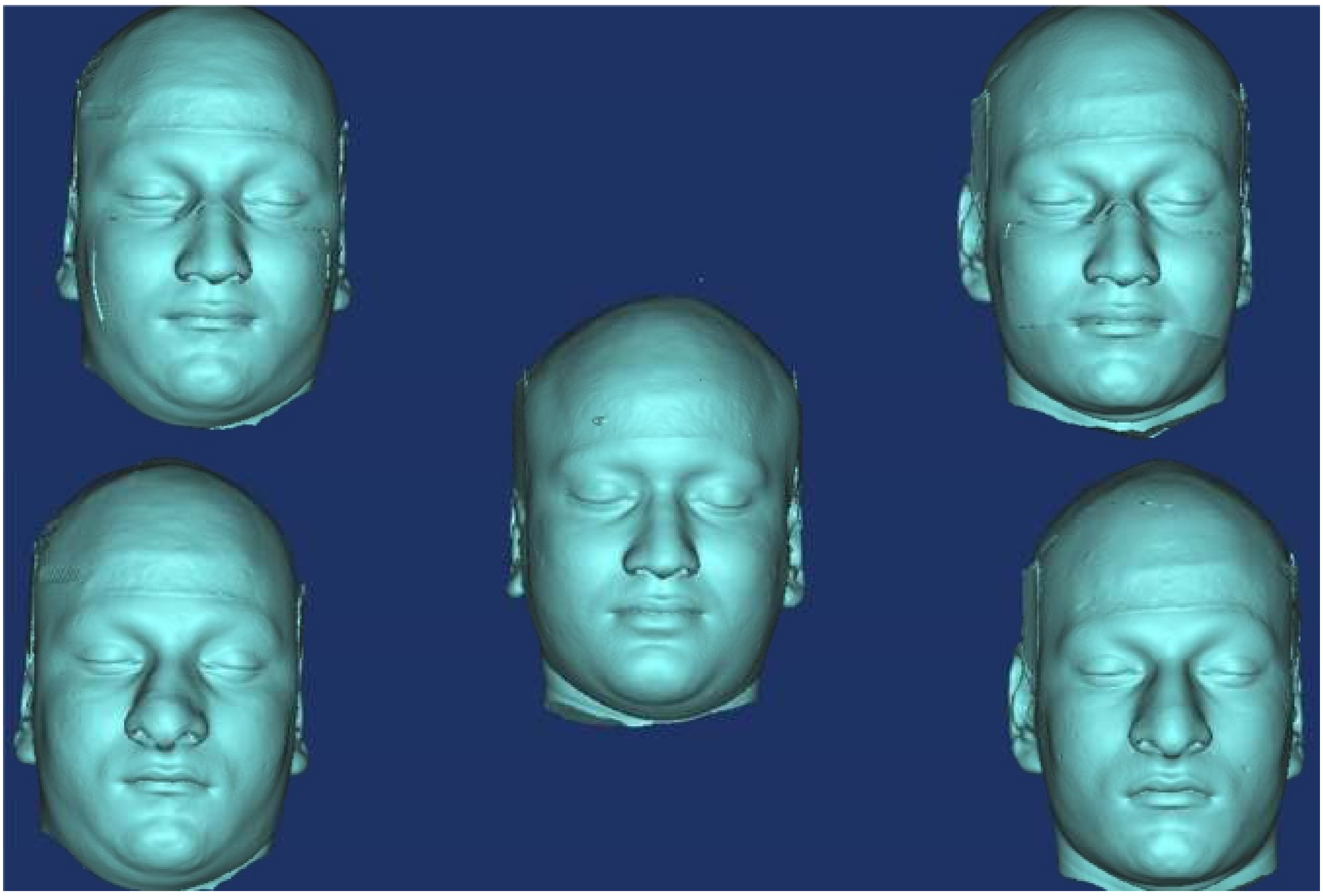


Figure 13. Representative of corresponding new facial identity (top) of recipients with different face index (bottom) resulting from face transplantation. Donor is shown in the center.

Aesthetic outcome of the face transplantation will depend upon number of craniofacial parameters that are identity compatible between recipient and donor. Scoring them will make easy to communicate identity issues with donor's family and recipient as well. "AM" scale, denoting letter M, is proposed in this study to quantify identity changes of face transplantation. Left and right limbs of M quantify identity transfer (A) and identity restoration (M) respectively. Lee and Freire[25] concluded that change in configuration of facial features affects the perception of geometric shape that comes in visual field of face and significantly distorts the overall perception of face. Moreover, vertical dimension has considerable effect on face perception. Based upon these attributes of face perception, highest score of two was given to identity compatible parameters of outer and inner optical environment while parameters of middle optical environment got highest score of one except Pr received two scores, considering the significance of vertical dimension. All identity incompatible parameters were given lowest score of zero. Therefore, cross face transplantation of identical twins results in high identity transfer (A-10) and recipient's native identity will be nearly restored (M-10).

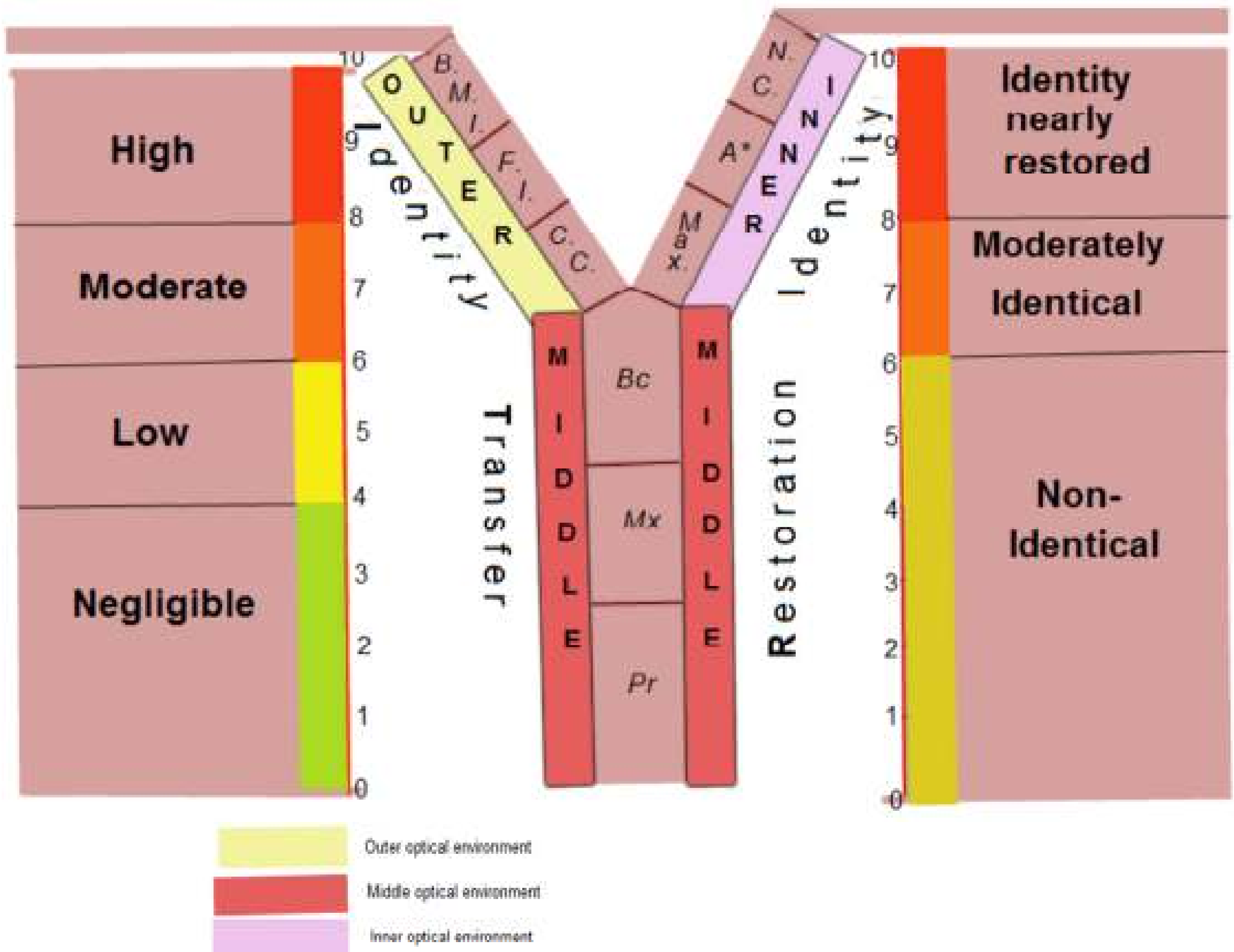


Fig 13. Diagrammatic representation of "AM" scale that quantifies identity changes of face transplantation.

Optical Environments	**Cranio-facial Parameters**		**Identity Compatible**	**Identity Incompatible**
Inner	1. Nose	Shape	1	0
		Length	1	0
	2.Maxillary Shape		2	0
	3.Mid-face Angle		2	0
Middle	1. Bc		1	0
	2. Pr		2	0
	3.Mx		1	0
Outer	1. BMI		2	0
	2. FI		2	0
	3. Chin	Shape	1	0
		Protuberance	1	0

Table 5. Identity scores used to quantify the Identity changes of Face Transplantation.

Humans use facial comparisons to recognize their relatives and regulate their behavior[20] therefore; face transplant recipients will have to cope with reactions of family and friends to their altered appearance[21]. If a recipient's new identity resembles his / her family members, it will be a psychological relief and relatively easy to adapt to social reactions. Family members share certain facial characteristics that make unique family phenotype. Morphometric method proposed in this study will help chose customized donor graft to give recipient an identity that can be a part of family phenotype.To achieve this objective, a family facial skeletogram for morphometric studies should be planned to find a family identical donor. Recently cone beam CT has been found more useful tool for dento-facial imaging because of reduced radiation exposure and favorable cost benefit analysis[22]. Family morphometric study can be particularly helpful to alleviate recipient's identity apprehensions when his or her pre-injury CT scan is not available to find the near identical match. Moreover, face donation may be encouraged if a donor's family knows their dead relative's graft will not be recognized; instead, it will become part of another family phenotype. Additional parameters like gender, skin color, and texture should be matched between donors and recipients: minimum morphological parameters should be used to find native or family identical match. Two types of parameters are proposed: Primary parameters are x-; z- coordinates of Bc, Pr respectively while secondary parameters are nose characteristics and mid face angle.

Morphometric methods and 3D image analysis can be useful tools to understand the bio-dynamics of facial identity; hence, predict and visualize possible identity changes to educate potential donors and recipients. This study can be helpful to 1) to measure identity issues of face transplantation. 2.) For organ banks to record the identity databases of facial grafts that can be used in future to choose appropriate graft in accordance with recipient's identity expectations from face transplantation 3.) To restore the facial symmetry of subjects those require treatment with facial implants for facial asymmetry, trauma and congenital deformities. 4.) To accurately measure the inheritance patterns of cranio-facial components keeping in mind the limitations of 2D methods.

A drawback of this study is small number of subjects. There needs collaboration among institutions to establish a twin research study with large sample size that measures and standardize bio-physical variations in morphology of craniofacial components.

Pomahac et al[6] predicted negligible appearance transfer through image editing of human color photographs. It was a subjective perception based study that didn't take into account the importance of third dimension which is essential to overall form and shape of an object. It is akin to a popular survey that records common opinion about morphological characteristics of a circular shape that in reality is a spherical object. It will be highly unethical for an institution to practice noble cause of face transplantation based upon such flimsy findings. If there is an identity transfer that patient did not expect; it will lead to an identity split, consequences of which would be grave if recipient failed to psychologically accept the organ and could not rebuild its social expression in everyday life[23]. Moreover, patient may feel that he was coerced into having surgery[21]. Such issues cannot be solved by research methods that are fragmented and are based on subjective psychological mindset.

Recently, United States Department of Defense (DoD) awarded research grant of $ 3.4 million to Brigham and Women hospital, a teaching affiliate of Harvard Medical School to perform face transplant on injured soldiers in Afghanistan and Iraq war[24]. Keeping in mind the aspects of war injuries and America's vast biological diversity, probability of identity transfer could be even higher. Identity changes of face transplant are one of its core issues and plastic surgeons have greater responsibility to rightly address this. If discipline of plastic surgery fails to solve this crucial aspect, it will only add to media's critical acclaim that face transplantation is merely a ticket to popularity for plastic surgeons.

Conclusion: Identity transfer may occur in face transplantation and this study can be used worldwide irrespective of race and ethnicity of the patients.

Acknowledgment: I am indebted to my family, especially my beloved Mom, Mrs. Urmila Devi's indispensable spiritual inspiration and support that was a guiding force to finish this study. I also thank my uncle, Mr. Vijay Garg who was instrumental in arranging the twins. Last, thanks to Materialise team at Michigan, US, particularly Eric Renteria, for the technical assistance regarding software.

References:

1. Thomas A, Obed V, Murarka A, Malhotra G. Total face and scalp replantation. Plast Reconstr Surg. 1998 Nov;102(6):2085-7

2. Dubernard JM, Devauchelle B. Face transplantation. Lancet. 2008 Aug 23;372(9639):603-4.

3. Swindell JS. Facial allograft transplantation, personal identity and subjectivity. J Med Ethics. 2007 Aug;33(8):449-53.

4. Siemionow M, Agaoglu G. The issue of "facial appearance and identity transfer" after mock transplantation: a cadaver study in preparation for facial allograft transplantation in humans. J Reconstr Microsurg. 2006 Jul;22(5):329-34.

5. Baccarani A, Follmar KE, Das RR, Mukundan S, Marcus JR, Levin LS, Erdmann D. A pilot study in sub-SMAS face transplantation: defining donor compatibility and assessing outcomes in a cadaver model. Plast Reconstr Surg. 2007 Jan;119(1):121-9.

6. Pomahac B, Aflaki P, Nelson C, Balas B. Evaluation of appearance transfer and persistence in central face transplantation: a computer simulation analysis. J Plast Reconstr Aesthet Surg. 2010 May;63(5):733-8

7. Siemionow M, Gordon CR. Overview of guidelines for establishing a face transplant program: a work in progress. Am J Transplant. 2010 May;10(5):1290-6. Epub 2010 Mar 26. PubMed PMID: 20353470.

8.Li, S. Z., ed., [Encyclopedia of Biometrics], vol. 1, Springer Science + Business Media (2009). Editorial Advisor: Anil Jain.

9. Todd JT. The visual perception of 3D shape. Trends Cogn Sci. 2004 Mar;8(3):115-21.

10. Pizlo Z, Sawada T, Li Y, Kropatsch WG, Steinman RM. New approach to the perception of 3D shape based on veridicality, complexity, symmetry and volume. Vision Res. 2010 Jan;50(1):1-11.

11. Savoye I, Loos R, Carels C, Derom C, Vlietinck R. A genetic study of anteroposterior and vertical facial proportions using model-fitting. Angle Orthod. 1998 Oct;68(5):467-70. PubMed PMID: 9770105.

12.Manfredi C, Martina R, Grossi GB, Giuliani M. Heritability of 39 orthodontic cephalometric parameters on MZ, DZ twins and MN-paired singletons. Am J Orthod Dentofacial Orthop. 1997 Jan;111(1):44-51

13. Krause, Wise and Frei, Heredity and Craniofacial complex. Am. J. Orthod,45: 172-217, 1959.

14. Dryden IL, Mardia KV. Statistical Shape Analysis. New York: John Wiley & Sons; 1998.

15. Enlow DH 1990 . The plan of the human face: Facial growth, 3rd edition ; W B saunders Co. pp 164-192.

16. Devauchelle B, Badet L, Lengele B, et al. First human face allograft: early report. Lancet 2006; 368: 203–09.

17. Clarke A, Butler PE. Facial transplantation: adding to the reconstructive options after severe facial injury and disease. Expert Opin Biol Ther 2005;5: 1539–46.

18. Bass WM. Human osteology: a laboratory and field manual. 3rd ed. Columbia, Mo: Missouri Archaeological Society; 1987.

19. Michiels G, Sather AH. Determinants of facial attractiveness in a sample of white women. Int J Adult Orthodon Orthognath Surg 1994: 9: 95–103.

20. Alvergne A, Oda R, Faurie C, Matsumoto-Oda A, Durand V, Raymond M. Cross-cultural perceptions of facial resemblance between kin. J Vis. 2009 Jun 30;9(6):23.1-10.

21. Morris PJ, Bradley JA, Doyal L, Earley M, Hagan P, Milling M, Rumsey N. Facial transplantation: a working party report from the Royal College of Surgeons of England. Transplantation. 2004 Feb 15;77(3):330-8.

22. Swennen GR, Schutyser F. Three-dimensional cephalometry: spiral multi-slice vs cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2006 Sep;130(3):410-6

23. Okie S. A brave new face. N Engl J Med 2006; 354: 889–94.

24. http://www.brighamandwomens.org/Departments_and_Services/surgery/services/PlasticSurg/Reconstructive/FaceTransplantSurgery/DODstudy.aspx

25.Lee K, Freire A. Effects of face configuration change on shape perception: a new illusion. Perception. 1999;28(10):1217-26.