Bulut, O, Liu, C-YJ, Gurcan, S and Hekimoglu, B

Prediction of nasal morphology in facial reconstruction: Validation and recalibration of the Rynn method

Prediction of nasal morphology in facial reconstruction: validation and recalibration of the Rynn method

Ozgur Bulut[a*]

Ching-Yiu Jessica Liu[b]

Safa Gurcan[c]

Baki Hekimoglu[d]

---

[a] Department of Paleoanthropology, Institute of Archaeological Sciences, Eberhard Karls Universität Tübingen, Germany

[b] Face Lab, Liverpool John Moores University, Liverpool, United Kingdom

[c] Department of Biostatistics, Faulty of Veterinary Medicine, Ankara University, Turkey

[b] Radiology Department, Yildirim Beyazit Training and Research Hospital, Ankara, Turkey

---

[*] Corresponding author. Tel.: +4917634926628.

E-mail address: ozgur.bulut@yahoo.com (O. Bulut).

Prediction of nasal morphology in facial approximation: validation and recalibration of the Rynn method

Abstract

Background: Prediction of the nose from the skull remains an important issue in forensic facial approximation. In 2010, Rynn et al. published a method of predicting nose projection from the skull. With this method, three craniometric measurements (x, y, z) are taken, and these are then used in regression formulae to estimate the nasal dimensions.
Aim: The purpose of this study was to examine and test the accuracy of the Rynn et al. method and if necessary to adapt the formulae for this population.
Subjects and methods: A sample of 90 CT scans of Turkish adults was used in the study. The actual and predicted dimensions were compared using t-test. The age of the individuals ranged from 20 to 40 years by sex.
Results: The descriptive statistics and correlations were calculated, and the actual and predicted measurements were compared. The differences between the actual and predicted values were statistically significant ($p<0.01$), with −1 mm for males and −1.5 mm for females. Validation accuracies ranged from 76-92% in females and 72-82% in males. Recalibration equation accuracies ranged from 88-100% in females and 90-100% in males.
Conclusion: The results showed that the recalibration of the Rynn et al. method and its formulae gave satisfactory results with less error and can be employed in facial approximation cases.

Keywords: Forensic anthropology; facial approximation; nasal morphology prediction

Introduction

Facial approximation is often used in forensic investigations to reconstruct a likeness of the dead from the skull [1–6]. The shape of the nose is supported by the cartilaginous portion, of which is often dehydrated, missing or degraded in post-mortem changes of the human body. From the work by Gerasimov since the 1950s, many research have investigated and developed different methods to predict the nasal projection and shape based on the skeletal portion of the nose [3,7–14]. Gerasimov's two-tangent profile prediction method still remains to be one of the most useful technique in nasal tip prediction [5,13,15]. Rynn measured more than 80 craniofacial landmarks of the nose, and 6 regression equations were established for the nose in profile. Rynn et al.[13] showed the position of the pronasale derived from the two-tangent method could be subjective, as the position of the tip can vary with the difference in nose shapes. Rynn et al.[13] method was tested on a Central European sample (n=86) and showed good performance with a low error of variance[16]. However, the morphological structure of the nose is an important feature to establish a biological profile including the ethnicity[17–26]. In addition, facial proportions, head shapes and head forms vary with race[27,28]. Cole[29], who considers the Turkic race to be a result of the mixture between Mongoloids and Caucasians. According to the written documents, the origins of the Turkish ancestry correspond to the northwest boundary of China, between the Altai and Ural mountains [30,31]. Several studies indicate the differences in head shape, and facial structures between the Turkish sample and the European sample, where craniofacial measurements of other ethnic samples are not valid for the Turkish population [17,32–34].

Rynn et al.'s [13] method was developed on CT scans of 79 North American adults. CT scans have allowed comparisons between hard and soft tissues of the nose. The method proposed by Rynn et al.[13] had been tested on other populations, and the accuracy varies between populations[16,35,36]. This study measured all 6 regression equations on CT scans of a Turkish population to see if Rynn et al.'s[13] method is applicable when used on a different population and if necessary to revise the formulae for this population.

Materials and Methods

The sample composed of CT scans of 90 adult individuals (40 males, 50 females) (Table 1), the data were obtained at the Diskapi Yildirim Beyazit Training and Research Hospital, Ankara, Turkey, for patients referred to the radiology clinic for diagnostic brain

CT scans. All the patients underwent CT scans for reasons not related to this study. The subjects with head trauma or any other facial deformities were excluded from the study. Among BMI categories (<20, 20-25, >25) as slender, normal and obese, only the subjects who fell into the normal BMI category were included.

A Mx8000 spiral CT scanner (Philips, Amsterdam, Netherland) with a voxel resolution of 0.5 mm was used to obtain the CT scans. Three-dimensional craniofacial data were created from the DICOM (Digital Imaging and Communications in Medicine) data acquired from the CT scans. Both soft and hard-tissue images were imported into specific software, Mimics Research 17.0 (Materialise NV, Leuven, Belgium), to visualize virtual 3D models of the skull and facial surface by a process of segmentation using density threshold, and interpolation of the CT data (Fig 1). The software was then used to take craniometric and cephalometric measurements on the virtual models.

The method to be tested was proposed by Rynn et al.[13], based on regression analysis of the nasal bone dimensions. The measurements of the actual hard tissue and the predicted soft tissue dimensions of the nose are illustrated in Fig 2. Statistical analyses were performed using SPSS 14.0 (SPSS Inc., Chicago, IL). The descriptive statistics and correlations were calculated, and the actual and predicted measurements were compared using t-test. P value of $p<0.05$ was considered statistically significant. Regression equations were also tested on a separate sample consisting of 20 individuals (17 males and 3 females) between the ages of 20 and 49 years from the same population.

This study was approved by the Ethics Committee of Diskapi Yildirim Beyazit Training and Research Hospital, Ankara, Turkey.

Results

The means and standard deviations of the actual and predicted measurements of the pronasale height (ProVert), anterior projection (ProAnt), anterior projection in the NPP and soft nasal dimensions for males and females are shown in Table 2 and 3. The differences between the actual and predicted nasal dimensions were found to be statistically significant in both sexes at the 0.01 levels. The mean error represents 2.4% of the actual nasal length in males and 5% in females. The mean error represents 1% of the actual nasal height in males and 1.6% in females. The mean error represents 5% of the actual nasal depth in both sexes.

On the other hand, the correlation between the actual and predicted values of nasal dimensions is significant in both sexes. The nasal length (nl), nasal height (nh) and nasal depth (nd) showed statistically significant correlation as 0.85, 0.78, 0.70 in males, 0.84, 0.81, 0.75 in females, respectively. Nasal length (nl) has the highest correlation value, whereas nasal depth (nd) is at the lowest correlation value in both sexes.

In general, this method underestimates all nasal dimensions: nasal length (nl); nasal height (nh) and nasal depth (nd) in both sexes. Mean differences in males were −1.11 mm, −0.89 mm and −1.05 mm of the nasal length (nl), nasal height (nh) and nasal depth (nd), respectively. In females, mean differences were −1.55 mm, −0.82 mm and −1.03 mm. These values showed that the proposed equations performed better in nasal length and nasal height for males and nasal depth for females. On the other hand, nasal height equation was the best in both sexes. The differences between the actual and predicted values just slightly exceeded −1 mm for males and −1.5 mm for females and were statistically significant ($p<0.01$).

Following the Rynn et al[13] method, Table 4 demonstrates the percentage of individuals whose pronasale position and nasal dimensions were reconstructed within a <1.5, <2.5 and <5 mm error. About 61-70% of the sample was within 1.5mm error, and 73-87% within 2.5 mm. 5mm is a large deviation considering the average length of the measurements. For example, the average measurement for Pronasal ant was 26mm in Female and 28mm in Male, yet only 84% of the total sample was within 5mm error. This suggests the Rynn et al[13] method may not be representative of this sample.

Six regression equations from Rynn et al. [13] was revised on this Turkish population and simplified as demonstrated in Table 5. The equations were separated into male and female with above 95% of the measurements being under 2.5mm of error.

Discussion

Correlation analysis of the actual measurements and predicted measurements were statistically significant (Table 2 and 3). All six nasal dimensions in Turkish males and females were underestimated by the Rynn et al.[13] method. When the regression equations were tested on a separate sample consisting of 20 individuals (Table 6), they performed to a very good level of accuracy, falling within ±2 mm. The largest error was a single underestimation of 2.4 mm. In comparison to other validation studies; based on a Central European population, Mala [16] suggested that ProAnt, ProFHP and Nasal Length were significantly different and underestimated, and Nasal Depth was significantly different and overestimated in both sexes.

Rynn et al. suggested Nasal height and Nasal depth for European females exhibited smaller ranges when compared to the European male subjects. Sarilita et al.[35] compared the Rynn et al.[13] method to an Indonesian population; their results indicated that all measurements were statistically different in both sexes, most measurements (ProAnt, ProFHP, Nasal Length, Nasal Height and Nasal Depth) were overestimated, and ProVert was underestimated.

Utsuno et al.[36] compared the nasal tip projection from Rynn et al.[13] to a Japanese population; the author reported an overestimation in two measurement comparisons. Sarilita et al.[35] and Utsuno et al.[36] was based on different East Asia populations and suggested mostly an overestimated of nasal dimension. Mala[16] and the current study both suggested mostly underestimation of nasal dimensions. Several studies regarding anthropometric measurements of the nose indicate that there are morphometrical and anthropometrical differences of the nasal dimensions in between ethnic groups[19–21]. It is also shown in the literature that the nasal shape and dimensions of the Turkish adults differs from the Asian populations [17,32,37,38]. Nasal shape variation between populations is often the explanation for such differences [35,36].

The current study presented sex separated estimation for each nasal dimensions. It is reported that males has proportionately larger noses than the females and it is usually more protrusive and longer, it has a more pointed tip with a tendency to be down turned. In addition, male noses usually ranged from straight to convex (aquiline), whereas female noses tended to range from straight to concave, with a tendency to tilt upwards [39–41]. Literature related to facial soft tissue thickness are often analyzed with the separation of sexes[42–50], specifically to nose prediction, Rynn et al.[13] and Sarilita et al.[35] both suggested significant sexual dimorphism.

Stephan et al.[51] suggested that the variation of facial soft tissue thickness within each sex was larger than between, the author suggested that although an individual landmarks may differ at statistically significant levels between the sexes, the clustering of the two groups is not strong enough to justify the use of sex specific soft tissue depth means in attempts to identify a single individuals. Indeed the variation within a group could be larger, and perhaps the variation in shape could be a bigger contributing factor. An average could not be representative of a single individual, and equations derived from a mean can only be a best estimate.

To achieve a best estimate, the significance of sexual dimorphism should not be diminished however small the differences are. In literature related to facial feminization surgery, the perceptual difference between the male and female nose is often a matter of a few millimeters[52–54]. If these subtle differences are perceptually noticeable, the small differences in nose prediction will perhaps have an effect on the identification process.

Conclusion

This research tested the Rynn et al.[13] method on a Turkish population sample, and the revised method introduces a more population specific predictions with less error. The results indicated that the recalibration of the Rynn et al. method gave satisfactory results with less error and can be employed in facial approximation cases. Rynn et al.'s [13] method is easy to apply and practical for facial approximation practitioners. We believe that this method makes a significant contribution to the process of rebuilding face onto the skull of an unidentified individual.

References

[1] B.P. Gatliff, Facial sculpture on the skull for identification, The American Journal of Forensic Medicine and Pathology. 5 (1984) 327–332.

[2] M. Gerasimov, The Face Finder, CRC Press, New York, 1971.

[3] W.M. Krogman, M.Y. Iscan, The human skeleton in forensic medicine, Charles C. Thomas, Springfield, 1986.

[4] J. Prag, R. Neave, Making Faces: Using Forensic and Archaeological Evidence., British Museum Press, London, 1997.

[5] C. Rynn, C.M. Wilkinson, Appraisal of traditional and recently proposed relationships between the hard and soft dimensions of the nose in profile, American Journal of Physical Anthropology. 130 (2006) 364–373.
[6] K.T. Taylor, Forensic art and illustration, CRC Press, New York, 2010.
[7] S.L. Davy-Jow, S.J. Decker, J.M. Ford, A simple method of nose tip shape validation for facial approximation, Forensic Science International. 214 (2012) 208–e1.
[8] R.M. George, The lateral craniographic method of facial reconstruction, J Forensic Sci. 32 (1987) 1305–30.
[9] K.-M. Lee, W.-J. Lee, J.-H. Cho, H.-S. Hwang, Three-dimensional prediction of the nose for facial reconstruction using cone-beam computed tomography, Forensic Science International. 236 (2014) 194–e1.
[10] G.A. Macho, Descriptive morphological features of the nose—an assessment of their importance for plastic reconstruction, Journal of Forensic Science. 34 (1989) 902–911.
[11] G.A. Macho, An appraisal of plastic reconstruction of the external nose, Journal of Forensic Science. 31 (1986) 1391–1403.
[12] M. Prokopec, D.H. Ubelaker, Reconstructing the shape of the nose according to the skull, Forensic Sci Commun. 4 (2002). https://www.fbi.gov/about-us/lab/forensic-science-communications/fsc/jan2002/prokopec.htm/ (accessed March 17, 2017).
[13] C. Rynn, C.M. Wilkinson, H.L. Peters, Prediction of nasal morphology from the skull, Forensic Science, Medicine, and Pathology. 6 (2010) 20–34.
[14] C.N. Stephan, M. Henneberg, W. Sampson, Predicting nose projection and pronasale position in facial approximation: a test of published methods and proposal of new guidelines, American Journal of Physical Anthropology. 122 (2003) 240–250.
[15] C. Wilkinson, Facial reconstruction–anatomical art or artistic anatomy?, Journal of Anatomy. 216 (2010) 235–250.
[16] P.Z. Mala, Pronasale position: an appraisal of two recently proposed methods for predicting nasal projection in facial reconstruction, Journal of Forensic Sciences. 58 (2013) 957–963.
[17] A. Uzun, H. Akbas, S. Bilgic, M. Emirzeoglu, O. Bostancı, B. Sahin, Y. Bek, The average values of the nasal anthropometric measurements in 108 young Turkish males, Auris Nasus Larynx. 33 (2006) 31–35.
[18] F.A. Ofodile, F.J. Bokhari, C. Ellis, The black American nose., Annals of Plastic Surgery. 31 (1993) 209–18.
[19] L.M. Milgrim, W. Lawson, A.F. Cohen, Anthropometric analysis of the female Latino nose: revised aesthetic concepts and their surgical implications, Archives of Otolaryngology–Head & Neck Surgery. 122 (1996) 1079–1086.
[20] K. Mishima, Y. Mori, T. Yamada, T. Sugahara, Anthropometric analysis of the nose in the Japanese, Cells Tissues Organs. 170 (2002) 198–206.
[21] K. Ochi, T. Ohashi, The effects of an external nasal dilator and nasal dimensions in Asians, Otolaryngology-Head and Neck Surgery. 126 (2002) 160–163.
[22] T. Romo Iii, M.T. Abraham, The ethnic nose, Facial Plastic Surgery. 19 (2003) 269–278.

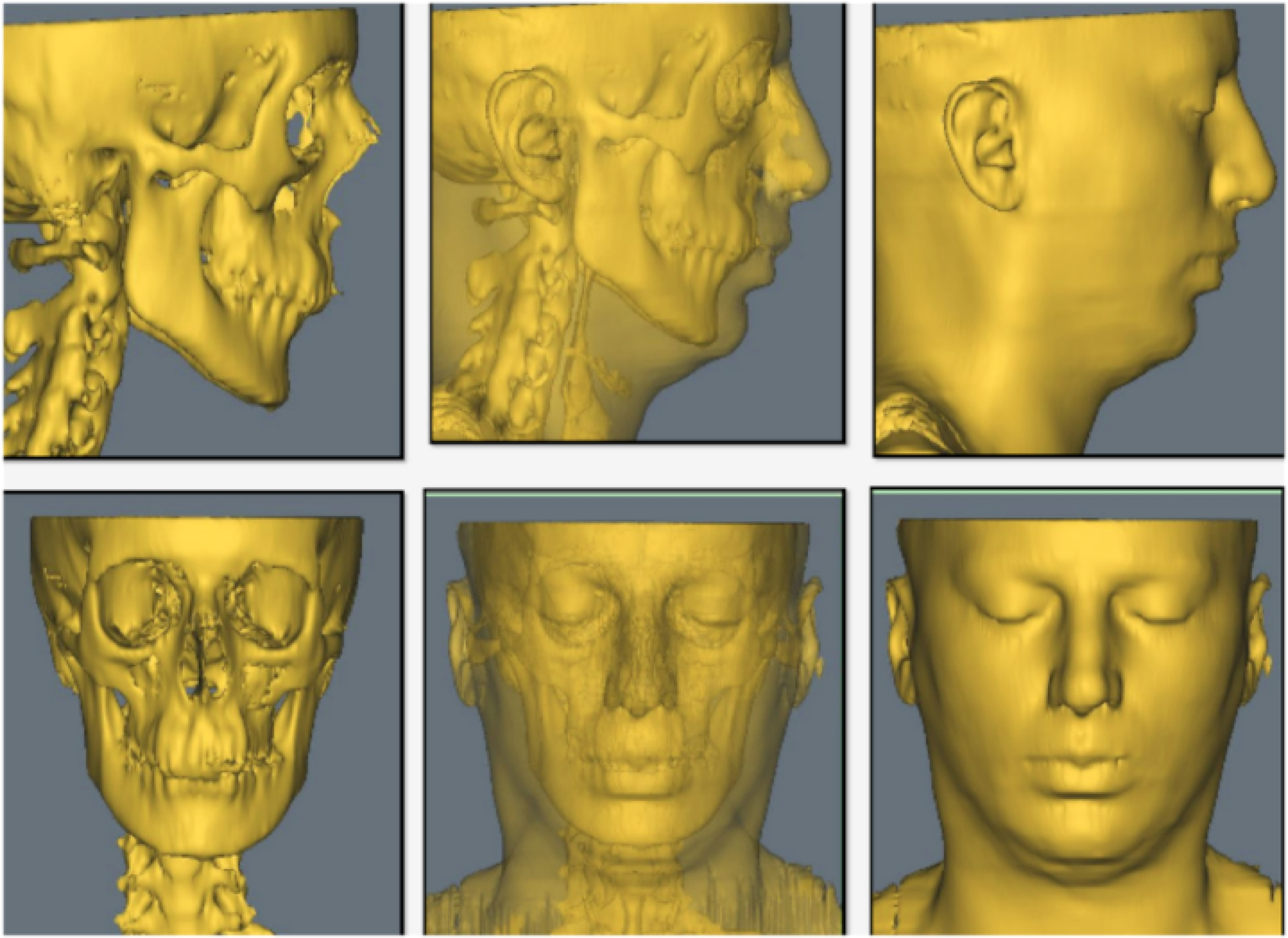
[23] V.F. Ferrario, C. Sforza, C.E. Poggio, J.H. Schmitz, Three-dimensional study of growth and development of the nose, The Cleft Palate-Craniofacial Journal. 34 (1997) 309–317.
[24] M.G. Bozkir, P. Karakas, Ö. Oguz, Vertical and horizontal neoclassical facial canons in Turkish young adults, Surgical and Radiologic Anatomy. 26 (2004) 212–219.
[25] S.C.L. Leong, P.S. White, A comparison of aesthetic proportions between the Oriental and Caucasian nose, Clinical Otolaryngology & Allied Sciences. 29 (2004) 672–676.
[26] A. Etöz, Anthropometric analysis of the nose, INTECH Open Access Publisher, 2011.
[27] W.F. Larrabee, K.H. Makielski, J.L. Henderson, Variations in facial anatomy with race, sex, and age, Surgical Anatomy of the Face. Philadelphia: Lippincott Williams & Wilkins. (2004) 22–8.
[28] P.M. Prendergast, Facial proportions, in: Advanced Surgical Facial Rejuvenation, Springer, 2012: pp. 15–22.
[29] S.M. Cole, Races of man, Trustees of the British museum (natural history), 1965.
[30] A.N. Kurat, I. XVIII, Yüzyıllarda Karadeniz Kuzeyindeki Türk Kavimleri ve Devletleri, Ankara, TTK Basımevi. (1972).
[31] A. Saatçioğlu, A survey on the racial types of anatolian skeletal remains, Ankara Üniversitesi DTCF Dergisi. 30 (1982) 193–210.
[32] Ö. Karaca, B. Gülcen, M.A. Kuş, F. Elmalı, İ. Kuş, Morphometric facial analysis of Turkish adults, Balıkesir Sağlık Bilimleri Dergisi. 1 (2012) 7–11.
[33] C. Sforza, G. Grandi, M. De Menezes, G.M. Tartaglia, V.F. Ferrario, Age-and sex-related changes in the normal human external nose, Forensic Science International. 204 (2011) 205–e1.
[34] E. Ozsahın, E. Kızılkanat, N. Boyan, R. Soames, O. Oguz, Evaluation of face shape in Turkish individuals, Int. j. Morphol. 34 (2016) 904–908.
[35] E. Sarilita, C. Rynn, P.A. Mossey, S. Black, F. Oscandar, Nose profile morphology and accuracy study of nose profile estimation method in Scottish subadult and Indonesian adult populations, International Journal of Legal Medicine. 132 (2018) 923–931.
[36] H. Utsuno, T. Kageyama, K. Uchida, K. Kibayashi, K. Sakurada, K. Uemura, Pilot study to establish a nasal tip prediction method from unknown human skeletal remains for facial reconstruction and skull photo superimposition as applied to a Japanese male populations, Journal of Forensic and Legal Medicine. 38 (2016) 75–80.
[37] F. Ozdemir, A. Uzun, Anthropometric analysis of the nose in young Turkish men and women, Journal of Cranio-Maxillofacial Surgery. 43 (2015) 1244–1247.
[38] U. Tuncel, A. Turan, N. Kostakoğlu, Digital anthropometric shape analysis of 110 rhinoplasty patients in the Black Sea Region in Turkey, Journal of Cranio-Maxillofacial Surgery. 41 (2013) 98–102.
[39] D.H. Enlow, M.G. Hans, Essentials of facial growth, W.B. Saunders Company, Philadelphia, 1996.

[40] P. Fernández-Riveiro, E. Smyth-Chamosa, D. Suárez-Quintanilla, M. Suárez-Cunqueiro, Angular photogrammetric analysis of the soft tissue facial profile, The European Journal of Orthodontics. 25 (2003) 393–399.
[41] A. Gulsen, C. Okay, B.I. Aslan, O. Uner, R. Yavuzer, The relationship between craniofacial structures and the nose in Anatolian Turkish adults: A cephalometric evaluation, American Journal of Orthodontics and Dentofacial Orthopedics. 130 (2006) 131–e15.
[42] H.-S. Hwang, M.-K. Park, W.-J. Lee, J.-H. Cho, B.-K. Kim, C.M. Wilkinson, Facial soft tissue thickness database for craniofacial reconstruction in Korean adults, Journal of Forensic Sciences. 57 (2012) 1442–1447.
[43] P. Panenková, R. Beňuš, S. Masnicová, Z. Obertová, J. Grunt, Facial soft tissue thicknesses of the mid-face for Slovak population, Forensic Science International. 220 (2012) 293–e1–e6.
[44] K. Gungor, O. Bulut, I. Hizliol, B. Hekimoglu, S. Gurcan, Variations of midline facial soft tissue thicknesses among three skeletal classes in Central Anatolian adults, Legal Medicine. (2015).
[45] O. Bulut, S. Sipahioglu, B. Hekimoglu, Facial soft tissue thickness database for craniofacial reconstruction in the Turkish adult population, Forensic Science International. 242 (2014) 44–61.
[46] N.H. de Almeida, E. Michel-Crosato, L.A.S. de Paiva, M.G.H. Biazevic, Facial soft tissue thickness in the Brazilian population: New reference data and anatomical landmarks, Forensic Science International. 231 (2013) 404–e1.
[47] S. Codinha, Facial soft tissue thicknesses for the Portuguese adult population, Forensic Science International. 184 (2009) 80–e1–e7.
[48] I.H. El-Mehallawi, E.M. Soliman, Ultrasonic assessment of facial soft tissue thicknesses in adult Egyptians, Forensic Science International. 117 (2001) 99–107.
[49] D. Sahni, G. Singh, I. Jit, P. Singh, Facial soft tissue thickness in northwest Indian adults, Forensic Science International. 176 (2008) 137–146.
[50] H. Utsuno, T. Kageyama, K. Uchida, K. Kibayashi, Facial soft tissue thickness differences among three skeletal classes in Japanese population, Forensic Science International. 236 (2014) 175–180.
[51] C.N. Stephan, R.M. Norris, M. Henneberg, Does sexual dimorphism in facial soft tissue depths justify sex distinction in craniofacial identification?, Journal of Forensic Science. 50 (2005) 1–6.
[52] I.N. Springer, O. Zernial, F. Nölke, P.H. Warnke, J. Wiltfang, P.A. Russo, H. Terheyden, S. Wolfart, Gender and nasal shape: measures for rhinoplasty, Plastic and Reconstructive Surgery. 121 (2008) 629–637.
[53] M.G. Shams, M.H.K. Motamedi, Case report: Feminizing the male face, Eplasty. 9 (2009).
[54] S.R. Nouraei, P. Randhawa, P.J. Andrews, H.A. Saleh, The role of nasal feminization rhinoplasty in male-to-female gender reassignment, Archives of Facial Plastic Surgery. 9 (2007) 318–320.

Figure captions

Fig. 1. Visualization of virtual 3D model of the skull and facial surface by density threshold, and interpolation of the CT data from frontal and lateral view

Fig. 2. Nasal dimensions are predicted by regression equations employing the craniometric measurements (1-Pronasale anterior projection from NPP; 2-Pronasale height down from nasion in NPP; 3-Pronasale projection in FHP; 4-Nasal length; 5-Nasal height; 6-Nasal depth) between cranial landmarks (nasion: midpoint of the fronto-nasal suture, rhinion: the most anteroinferior point on the nasal bone, acanthion: anterior extremity of the intermaxillary suture, subspinale: the deepest point of the subspinal concavity)



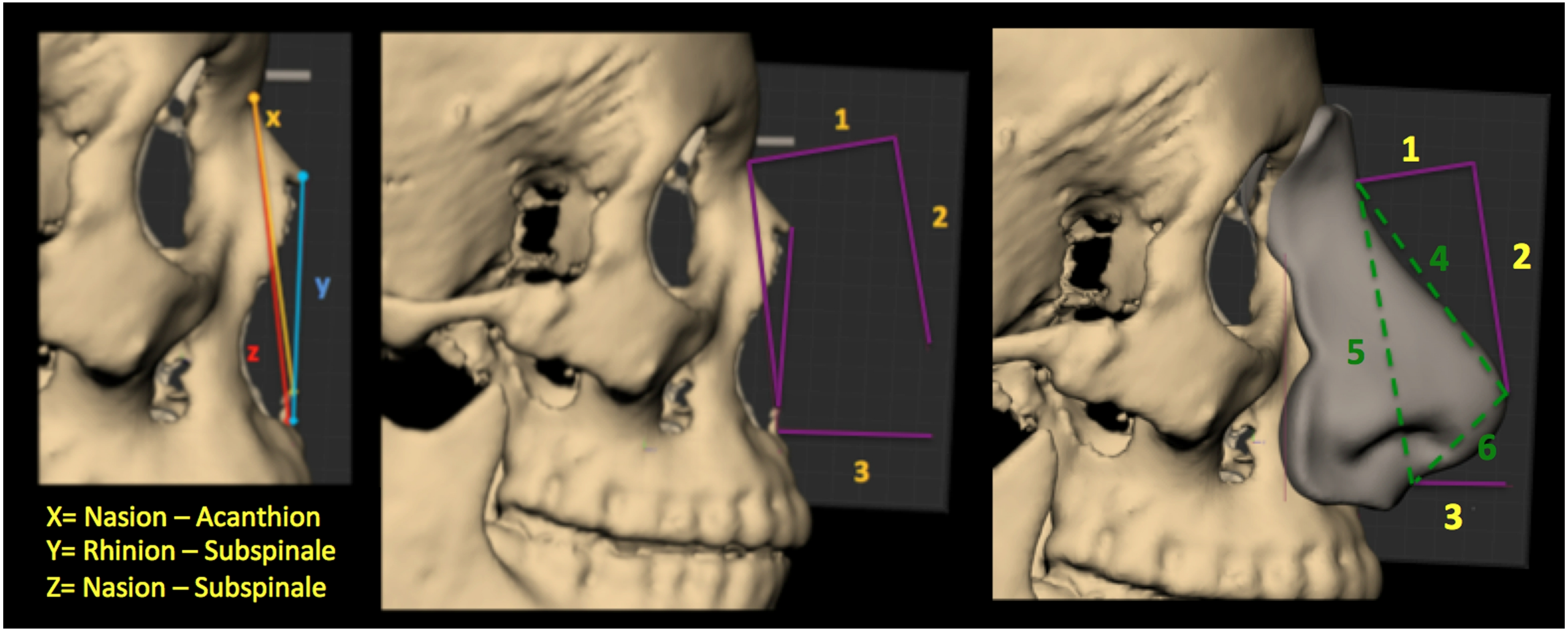

x
y
z
X= Nasion – Acanthion
Y= Rhinion – Subspinale
Z= Nasion – Subspinale
1
2
3
1
2
3
4
5
6

Table 1:
Ages of individuals by sex

Sex	Min Age	Max Age	Std	Mean
Male	21	48	8,21	34,96
Female	20	49	8,63	33,72

Table 2: Comparison of the predicted and actual values of nasal projection and nasal dimensions using the method of *Rynn et al.* [13] in males.

Number of Regression Equation Variable	Pronasal ant	Pronasal vert	Pronasal FHP	Nasal length	Nasal height	Nasal depth
Actual mean (mm)	28,36	47,51	29,42	47,09	54,84	20,93
Standart deviation(mm)	2,41	3,73	2,57	3,28	3,15	1,31
Predicted mean(mm)	27,35	46,17	28, 45	45,97	53,94	19,88
Standart deviation(mm)	2,35	3,32	2,60	2,91	3,05	1,15
Mean difference (mm)	-1,01*	-1,34*	-0,97*	-1,11*	-0,89*	-1,05*
p-Value(t-test)	0,000	0,000	0,000	0,000	0,000	0,000
Correlation	0,87	0,91	0,84	0,85	0,78	0,70
Mean difference as percentage of the actual dimension	3,45	2,82	2,61	2,35	0,98	5,01

*p<0,01

Table 3: Comparison of the predicted and actual values of nasal projection and nasal dimensions using the method of *Rynn et al.* [13] in females.

Number of Regression Equation Variable	Pronasal ant	Pronasal vert	Pronasal FHP	Nasal length	Nasal height	Nasal depth
Actual mean (mm)	26,34	45,79	27,36	45,76	52,54	19,86
Standart deviation(mm)	2,03	2,56	2,00	2,28	2,17	1,15
Predicted mean(mm)	25,32	43,85	26,26	44,21	51,72	18,87
Standart deviation(mm)	2,03	2,73	2,09	2,32	1,90	1,10
Mean difference (mm)	-1,02*	-1,94*	-1,10*	-1,55*	-0,82*	-1,03*
p-Value(t-test)	0,000	0,000	0,000	0,000	0,000	0,000
Correlation	0,75	0,88	0,91	0,84	0,81	0,75
Mean difference as percentage of the actual dimension	3,75	4,23	4,02	5,06	1,56	4,98

*p<0,01

Table 4: The percentage of individuals whose pronasale position and nasal dimensions were reconstructed within a 1,5 mm, 2,5 mm and 5 mm error from the actual dimension

	Pronasal ant	Pronasal vert	Pronasal FHT	Nasal length	Nasal height	Nasal depth
Total sample (n=90)						
% of cases within a 1,5-mm error	61,1	61,1	62,2	52,2	70	64,4
% of cases within a 2,5-mm error	76,6	74,4	73,3	81,1	83,3	86,6
% of cases within a 5-mm error	84,2	88,8	95,8	91,4	98	99
Males(n=40)						
% of cases within a 1,5-mm error	60	52,5	62,5	52,5	67,5	57,5
% of cases within a 2,5-mm error	75	72,5	77,5	82,5	80	80
% of cases within a 5-mm error	83,7	87,2	95,6	93	98	100
Femeles(n=50)						
% of cases within a 1,5-mm error	60	68	62	52	72	70
% of cases within a 2,5-mm error	78	76	78	80	86	92
% of cases within a 5-mm error	86,2	90	96	90,1	98	98

Table 5: Revised regression equations for prediction of nasal dimensions. (Correlation coefficients (R); linearity of relationship (R^2) and error indicated by residual error plot).

Equation number	Predicted dimension		Simplifed equation	Relevant sex	R	R^2	<1,5 mm error(%)	<2 mm error(%)	<2,5 mm error (%)
1.	Pronasale ant	This study	2,711 + 0,681Y	Females	0,75*	0,57	84	90	95,6
			-0,481 + 0,776Y	Males	0,92*	0,85	90	100	100
		Rynn's method	0.83Y - 3.5	All	0.74	0.66			68.9
2.	Pronasale vert	This study	5,501 + 0,779X	Females	0,86*	0,74	82	88	96,3
			-3,53 + 0,954X	Males	0,95*	0,91	85	97,5	100
		Rynn's method	0.9X - 2	All	0.83*	0.68			82.8
3.	Pronasale FHP	This study	1,161 + 0,775Y	Females	0,84*	0,71	80	88	97
			0,518 + 0,777Y	Males	0,87*	0,75	80	90	99
		Rynn's method	0.93Y - 6	All	0.84*	0.70			65.5
4.	Nasal length	This study	6,624 + 0,71Z	Females	0,93*	0,88	84	98	100
			0,764 + 0,807Z	Males	0,97*	0,94	85	97,5	100
		Rynn's method	0.74Z + 3.5	All	0.77*	0.60			87.0
5.	Nasal height	This study	15,047 + 0,687Z	Females	0,94*	0,89	90	96	100
			9,858 + 0,784Z	Males	0,97*	0,95	87,5	97,5	100
		Rynn's method	0.63Z + 17	Females	0.73*	0.53			81.8
			0.78Z + 9.5	Males	0.77*	0.58			76.4
6.	Nasal depth	This study	5,169 + 0,423Y	Females	0,82*	0,68	90	100	100
			6,587 + 0,386Y	Males	0,84*	0,71	90	100	100
		Rynn's method	0.5Y + 1.5	Females	0.66*	0.43			92.8
			0.4Y + 5	Males	0.58*	0.34			78.5

*p<0,01

Table 6. Error of regression equations when tested on a separate sample of the same population

No	Sex	Age Range	Regression Equations and Error (mm)					
			Pronasal Ant	Pronasal Vert	Pronasal FHP	Nasal Length	Nasal Height	Nasal Depth
1	M	20-49	0.5	0.7	0.7	0.1	0.3	02
2	M	20-49	1.0	0.3	1.1	0.5	0.4	0.8
3	M	20-49	0.8	0.6	0.4	0.5	0.7	0.7
4	M	20-49	0.5	0.3	2.2 *	1.1	1.8	0.9
5	M	20-49	1.2	0.8	1.1	1.8	1.4	1.1
6	F	20-49	0.9	1.1	0.9	0.6	1.2	0.9
7	M	20-49	1.2	0.5	1.4	0.5	1.8	0.8
8	M	20-49	0.8	0.5	0.9	0.9	1.4	0.9
9	M	20-49	2.1*	2.2*	0.9	2.4*	0.6	1.1
10	M	20-49	1.0	0.5	1.5	1.8	0.8	1.2
11	M	20-49	1.4	1.0	1.6	1.8	1.2	1.4
12	F	20-49	1.3	1.1	0.6	1.0	0.4	0.8
13	M	20-49	1.9	1.7	0.9	1.4	1.0	0.5
14	M	20-49	1.4	1.3	1.1	1.7	1.8	0.7
15	M	20-49	1.8	1.3	1.0	1.0	1.3	0.9
16	M	20-49	1.5	1.4	1.3	1.1	1.5	0.6
17	M	20-49	1.3	1.1	0.6	0.8	1.1	0.8
18	M	20-49	0.8	0.8	0.5	1.0	0.5	0.9
19	F	20-49	0.5	0.4	0.6	0.9	0.6	1.0
20	M	20-49	0.9	1.1	0.6	1.8	1.1	0.7

*Indicates error >2 mm