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Comparative Analysis of Facial Morphology between Okinawa Islanders and Mainland Japanese using Three-dimensional Images

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Abstract

Objectives: Differences in facial height and breadth between Okinawa Islanders and mainland Japanese have been reported in previous craniometric and somatometric studies. This study using three-dimensional (3D) images aimed to identify more detailed characteristics of facial morphology in each population.

Methods: Using a hand-held 3D scanner, we obtained 60 facial surface images each from Okinawa Islanders and mainland Japanese. Twenty-one landmarks were plotted on a computer and 27 measurements of distances and angles between the landmarks were taken. Statistical analyses such as *t* test, principal component analysis (PCA), regression analysis, and discriminant analysis were performed to identify sex and regional differences, the patterns of facial features, factors explaining the facial patterns, and other features.

Results: Okinawa Islanders showed lower facial and nasal heights than mainland Japanese. Furthermore, we identified larger protrusions of the glabella and nasal root in Okinawa Islanders than in mainland Japanese. In the PCA, we observed components of facial shape patterns. These components mainly represented facial size (PC1), facial depth (PC2), the prominence of the glabella and nasal root (PC3), and facial breadth (PC4). We identified that the population difference is strongly associated with PC3.

Conclusions: This study quantitatively identified differences in the facial morphology between Okinawa Islanders and mainland Japanese using 3D digital images, with special emphases on the differences in the nasal height and the prominence of the glabella and nasal root.

Key words: facial morphology, three-dimensional images, Okinawa Islanders, mainland Japanese

Introduction

Human facial morphology is a subject that attracts general interest. We identify individuals predominantly by face and recognize even small facial differences. Furthermore, we primarily judge the attractiveness of an individual by their face. Facial variation and its recognition are important for understanding human social behaviors.

We also find regional/population differences in facial features. It has classically been considered that the differentiation of facial morphology among populations was caused by adaptations to the environment such as climate (Hylander, 1977; Steegmann et al., 2002), while the adaptive significance of facial variation is not fully understood. Alternatively, it has been hypothesized that assortative mating triggered the facial differentiation among populations (Penton-Voak et al., 1999; DeBruine et al., 2010; Little et al., 2011). However, the possibility remains that facial shapes diversified under neutrality.

A number of studies have investigated the craniofacial morphology of Japanese. In studies on ancient bones, researchers have found many morphological differences between prehistoric Japanese populations. Indigenous hunter-gatherers of the Japanese archipelago in the Jomon period (approximately from 16,000 to 2,500 BP) (Habu, 2011) retained cranial characteristics of the Paleolithic Asians even in the Neolithic age (Hanihara, 1991; Kamminga, 1992; Brace et al., 2001). In contrast, rice-farming people who migrated from the Asian continent, probably via the Korean peninsula, to the Japanese archipelago at the beginning of the Yayoi period had similar features as the Neolithic Chinese. Crania of Jomon people displayed low facial height, square orbit, and small teeth, whereas crania of Yayoi migrants possessed wholly large and flat features with large facial height, round orbits, and large teeth (Suzuki, 1981; Brace and Nagai, 1982; Yamaguchi, 1982; Brown, 1999; Ishida, 1992; Doi, 2003; Hanihara and Ishida, 2009).

Regional differences in craniofacial morphology have also been observed within present-day people of the Japanese archipelago. People in mainland Japan have similar cranial characteristics to Yayoi migrants, whereas the Ainu living in Hokkaido, the northernmost part of Japan, and people in the Ryukyu Islands, the southernmost part of Japan, relatively retain cranial features of the Jomon people (Hanihara, 1991; Watanabe et al., 2004), although there were some differences between the two present populations (Miyake, 1940; Suda, 1950; Pietrusewsky, 1999, 2004; Dodo et al., 2000). These facts have provided supporting evidence for the "Ainu-Ryukyu common origin" (von Baelz, 1911) and "dual structure model" (Hanihara, 1991) hypotheses regarding the population history of the Japanese. These hypotheses argue that regional differences in physical characteristics were caused by the varying rates of intermixture between the Jomon people and the Yayoi migrants, which have also been supported by genetic studies (Omoto and Saitou, 1997; Yamaguchi-Kabata et al., 2008; HUGO Pan-Asian SNP Consortium, 2009; Koganebuchi et al., 2012; Japanese Archipelago Human Population Genetics Consortium, 2012).

Supposing that the characteristics of the Ainu and the Ryukyuans are related with those of the Jomon people, studies on these present populations can further our knowledge about the Jomon people. Studies on living people will qualitatively and quantitatively compensate for the limited information obtained from excavated ancient bones, especially on characteristics in soft tissues. Based on somatometric measurements, it has been revealed, for example, that the Ryukyuans have shorter stature, lower facial height, lower nasal height, and broader face than mainland

Japanese (Suda, 1940; Naito, 1976). However, such classic morphological studies examined only a limited number of measurements since they relied on direct measurements of distances and angles between physical landmarks using an anthropometer and a goniometer (Knussmann, 1988; Farkas et al., 2005).

Recent advances in imaging technology allow three-dimensional (3D) images to be captured from an object and analyzed on a computer (Mori et al., 2003). Morphological analyses based on 3D images can easily increase the number of landmarks and measurements without inconveniencing the subjects (Ferrario et al., 2005; Toma et al., 2012; Vezzetti and Marcolin, 2012). In this study, to identify respective facial characteristics of mainland Japanese and Okinawa Islanders, we captured facial surfaces using a 3D digital scanner and analyzed in detail the facial morphology of these populations.

Materials and Methods

Subjects

We collected facial data from 120 adult volunteers living on Okinawa Island, one of the main Ryukyu Islands. For each sex, 30 individuals of mainland Japanese origin and 30 individuals of Okinawa Island origin were selected. In this study, mainland Japanese and Okinawa Islanders are defined as individuals whose four grandparents were all born in mainland Japan and on Okinawa Island, respectively (Table 1). The ages of the subjects ranged from 19 to 37 years, and the mean ages of the four groups ranged from 22 to 24 years. Mainland Japanese were significantly taller than Okinawa Islanders. This study was approved by the ethics committee of the University of the

Ryukyus. All subjects provided written informed consent to participate in this research project.

Scanning facial 3D images

Facial surface 3D images were acquired using a hand-held 3D digital scanner (Z-Scanner® 700CX, Z Corporation). The scanning resolution is 0.1 mm in height, width, and depth, and the accuracy of scanned data is up to 0.05 mm. During scanning, the subjects wore a board with reflective targets while in a sitting posture, and were asked to display a neutral facial expression with the eyes closed and the teeth occluded. The scanning of the facial surface took approximately 2 min.

Image data processing

We used image analysis software (Geomagic Qualify11, Geomagic) to process the 3D image data. After filtering noise and filling holes in the surface image data, 21 landmarks were manually plotted on the facial surface, as shown in Table 2 and Figure 1. These landmarks followed those defined by Martin (Knussmann, 1988). The 14 bilateral landmarks include the entocanthion (En) and ectocanthion (Ex) on the eyelids, the zygion (Zy) and condylion laterale (Cdl) on the cheeks and near the ears, the alar curvature (Ac) on the nose, the chellion (Chl) on the mouth, and the gonion (Go) on the jaw. The seven landmarks were the glabella (G), sellion (Se), pronasale (Prn), subnasale (Sn), labrale superius (Ls), labrale inferius (Li), and supragnathion (Sgn) on the mid-sagittal plane. We also obtained the midpoint of bilateral Ens, Acs, and Cdls as En(m), Ac(m), and Cdl(m), respectively.

After the coordinates of the landmarks were obtained, distances between two and angles between three representative points were measured (Figure 2). To observe the ruggedness of landmarks on the mid-sagittal plane, we defined a reference plane (RP) using three points, the right Ac, left Ac, and En(m), and calculated distances between the RP and each mid-sagittal landmark (Figure 2f). A total of 27 measurements were obtained (Table 3).

Statistical analyses

Sex and population differences were examined by Student's *t* test and Welch's *t* test after equality of variances were confirmed. To combine the results of separate tests for each sex, meta-analysis using the inverse variance method was performed. The level of statistical significance was set at $P < 0.05$. In addition, correction for multiple testing was done using the Benjamini–Hochberg method with a false discovery rate (FDR) < 0.1 or < 0.05. Principal component analysis (PCA) was carried out using the standardized 27 measurements as variables to characterize the pattern of facial features. Multiple regression analysis was also used to understand which variables (sex, region, body height, and body mass index [BMI]) explain facial features. Furthermore, discriminant analysis based on the 27 variables or variables selected by the stepwise method was performed, and the discrimination accuracy was evaluated with and without leave-one-out cross-validation. Statistical analyses were conducted using Excel 2007 (Microsoft Office for Windows®) and IBM SPSS statistics 19 (SPSS Inc.).

Results

Sex differences

Table 3 summarizes the results of measurements for each region for each sex. All the distance measurements except for the Ls-RP, Li-RP, and Sgn-RP were larger in males than in females at $P < 0.05$. Meanwhile, the angles of G-Se-Prn and En-Se-En were larger in females than in males.

Differences between Okinawa Islanders and mainland Japanese

In both sexes, Okinawa Islanders had a smaller facial height (G-Sgn) than mainland Japanese at $P < 0.05$ (Table 3). Especially, the nasal height (Se-Sn) showed a remarkable difference. The height of the lower face (Sn-Sgn) was smaller in Okinawa Islander females than in mainland Japanese females. Okinawa Islander females also had a smaller depth at En(m)-Cdl(m). In contrast, Okinawa Islanders had greater G-RP and Se-RP distances than mainland Japanese in both sexes. The distances from RP to mid-sagittal landmarks below Prn (Prn-RP, Sn-RP, Ls-RP, Li-RP, and Sgn-RP) were not different between Okinawa Islanders and mainland Japanese.

The meta-analysis combining the results for different sexes showed that, in addition to the aforementioned measurements, population differences at $P < 0.05$ were observed in Ex-Ex, Go-Go, G-Se-Prn, En-Se-En, and Ac(m)-Se-Prn (Table 3). After the correction for multiple testing by the Benjamini–Hochberg method with FDR < 0.1, eight measurements, G-Sgn, Se-Sn, Sn-Sgn, Ex-Ex, En(m)-Cdl(m), G-RP, Se-RP, and En-Se-En, were significantly different between the populations (Table 3). With FDR < 0.05, however, only four measurements, G-Sgn, Se-Sn, G-RP, and Se-RP, showed statistically significant differences.

Facial patterns observed by PCA

The results of PCA are shown in Table 4. The eigenvalues from the first to the seventh principal components (PCs) exceeded 1.0, and the seven PCs accounted for

79.6% of the total variance.

PC1 (eigenvalue, 7.8; contribution, 28.9%) was positively associated with facial heights, breadths, and depths (Figure 3), and thus can be interpreted as a size-related component. Since males have a larger face than females, PC1 also represented sex differences (Figure 4a). The angles of the G-Se-Prn and En-Se-En, which were larger in females than males, were negatively associated with PC1.

PC2 (eigenvalue, 3.8; contribution, 14.0%) was associated positively with the relative protrusion of the lower face that was indicated by Sn-RP, Ls-RP, Li-RP, and Sgn-RP, and negatively with the depth of the upper face, En(m)-Cdl(m) and Ac(m)-Cdl(m) (Figure 3). This result suggests that PC2 represents the variation in the upper and lower facial depths. Individuals with relatively small Ac(m)-Cdl(m) essentially have a protruded lower face and also have an anteverted RP because of the position of Acs (Figures 5a and b); these factors together will yield large values of Sn-RP, Ls-RP, Li-RP, and Sgn-RP. Moreover, PC2 was related to the shape of the nasal root; PC2 was correlated with a lower position of Se (i.e., larger G-Se and smaller Se-Sn) as well as with a greater concavity of the nasal root (smaller G-Se-Prn). Using all the individuals, we confirmed that G-Se/G-Sn is negatively correlated with Se-RP/G-RP ($r = 0.361$, $p = 5.05E-05$) (Figure 5c).

PC3 (eigenvalue, 3.1; contribution, 11.4%) was associated with a smaller protrusion of the upper face, especially at G-RP and Se-RP, and a larger angle of En-Se-En (Figure 3). As the univariate comparisons indicated (Table 3), these measurements were largely different between the populations. Figure 4b shows that Okinawa Islanders had, on average, small PC3 scores compared with mainland Japanese.

PC4 (eigenvalue, 2.5; contribution, 9.4%) was associated with the facial breadth

(Table 4). As for PC5 and higher PCs, however, it is difficult to give a concise interpretation since these PCs can include statistical artifacts generated after the extraction of lower PCs.

Factors associated with facial patterns

Multiple regression analysis for each of PC scores was performed to identify factors associated with PCs. We took into account sex (male = 0; female = 1), population (mainland Japanese = 0; Okinawa Islander = 1), body height, and BMI as explanatory variables. The results are summarized in Table 5. The PC1 score showed a negative correlation with sex and positive correlations with body height and BMI. The PC2 score was not related with any variables. The PC3 score was significantly associated with being female and mainland Japanese and higher BMI, while PC4 and PC5 were sex-related components. The population was also associated with the PC6 and PC7 scores.

Prediction of population membership by facial morphology

Discriminant analyses using the 27 measurements were performed to see whether these data can predict the population membership of individuals. The analyses were done for three types of data sets: all (males and females combined), males, and females. When all 27 measurements were included as variables, we obtained 80.0–91.7% accuracies without cross-validation (Table 6). However, the cross-validation accuracies decreased to 55.0–70.8%. This suggests that the increased accuracies without cross-validation were due to overfitting. When discriminant analyses were done using the stepwise method, only two variables, Se-Sn and G-RP, were selected in all three data sets, and the accuracies without cross-validation (70.0–80.0%) were comparable to the cross-validation accuracies (66.7–80.0%). Under cross-validation, the prediction using the two variables was more accurate than that using the 27 variables. These results indicated that Se-Sn and G-RP are good indicators for discriminating Okinawa Islanders from mainland Japanese.

Discussion

Our 3D facial measurements clearly demonstrated that Okinawa Islanders have lower facial and nasal heights (G-Sgn and Se-Sn) than mainland Japanese, as reported in previous somatometric studies (Suda, 1940; Naito, 1976). These characteristics have also been emphasized in several craniometric studies (Hsu, 1948; Ikeda, 1974; Fukase et al., 2012). We observed that the angle of Ac(m)-Se-Prn is larger in Okinawa Islanders than in mainland Japanese but that the nasal prominence (Prn-RP) is not much different between the populations. Therefore, the difference in Ac(m)-Se-Prn is likely to be due to the difference in the nasal height.

A previous somatometric study has shown that Okinawa Islanders have a broader bizygomatic breadth than mainland Japanese from Kyusyu (Naito, 1976). In studies of early modern crania, it has also been reported that the bizygomatic, biorbital, and mandibular breadths are broader in crania from the Okinawa Islands than those from mainland Japanese (Hsu, 1948; Fukase et al., 2012). Therefore, a broad face has generally been considered to be a characteristic of Okinawa Islanders. However, the present study demonstrated that Okinawa Islanders have significantly narrower Ex-Ex and Go-Go than mainland Japanese. We also observed a similar tendency at Zy-Zy, although the difference is not significant. We are currently unable to specify the reason for this discrepancy between previous and present studies. Variations in facial breadth have been observed within the population on Okinawa Island; people from the southern part of the island have a narrower face than people from the northern and middle parts (Naito, 1976). Such a regional difference on the island and/or a secular change may be involved.

The present study indicated that notable characteristics of Okinawa Islanders are prominent glabella and nasal root (G-RP, Se-RP, and En-Se-En). The prominent glabella and nasal root can be caused by the receding medial angles of the eyes since Okinawa Islanders have a smaller En(m)-Cdl(m). It has been reported that the Ryukyuans tend to have smaller eyeballs (Tomoyose et al., 2010), which would shift the medial angles of the eyes backwards. Considering these points, Okinawa Islanders can be regarded as having a well-defined and less flat upper face compared with mainland Japanese.

Dodo et al. (2000) argued that the Ryukyuans including the Amami, Okinawa, and Sakishima Islanders have a flatter facial skeleton than the Jomon, modern mainland Japanese, and the Ainu, based on three indices (i.e., subtense/chord) at the frontal, simotic, and zygomaxillary regions used to evaluate transverse flatness (Yamaguchi, 1973). However, Fukase et al. (2012) recently pointed out that Ryukyuan faces are not flat from the lateral view when compared with mainland Japanese faces. Although the Jomon and the Ainu have a larger simotic subtense, i.e., more prominent nasal root, than mainland Japanese and the Ryukyuans, the difference in the simotic index between mainland Japanese and the Ryukyuans is likely to result from the larger simotic chord in the Ryukyuans than in mainland Japanese (Yamaguchi, 1973; Dodo et al., 2000; Hanihara, 2000; Fukase et al., 2012). Consequently, Okinawa Islanders have a broader nasal bone and simultaneously larger depth from the eye to the nasal root than mainland Japanese.

In the PCA, we observed components of facial shape patterns. These components mainly represented facial size (PC1), facial depth (PC2), the prominence of the glabella and nasal root (PC3), facial breadth (PC4), and so on. As a facial shape pattern, we also found a correlation between the vertical and horizontal positions of Se; as the concavity of the nasal root becomes greater, the position of Se becomes lower. We identified that population difference is associated with PC3, PC6, and PC7, and that other factors such as sex, height, and BMI also influence facial patterns. Interestingly, PC2 did not have any relation with sex and body size. This may imply that the morphological variation represented by this component may be predominantly determined by genetic factors.

Recent rapid development of genomic technology has enabled the identification of genetic factors that contribute to physical traits. However, despite high heritability of facial characteristics (Nakata et al., 1974, Kau et al., 2005), only a few genetic variants have been identified to be associated with the facial morphology in genome-wide association studies (Paternoster et al., 2012; Liu et al., 2012). In these studies, one of the reliable associations has been observed at single nucleotide polymorphisms (SNPs) on the *paired box 3* (*PAX3*) gene, which plays critical roles during fetal development. These SNPs on *PAX3* are associated with the position of the nasion (sellion) relative to the midentocanthion. The present study also found a large variation in the position of the sellion. In the Japanese populations, the same genetic variants may be associated with this trait.

Meanwhile, a number of studies have demonstrated genetic differentiation between mainland Japanese and the Ryukyuans (Horai et al., 1996; Yamaguchi-Kabata et al., 2008; HUGO Pan-Asian SNP Consortium, 2009; Matsukusa et al., 2010;

Koganebuchi et al., 2012; Japanese Archipelago Human Population Genetics Consortium, 2012). The differences in craniofacial characteristics between the populations are likely to be caused by the differences in the frequencies of causal genetic variants. It has been revealed that a nonsynonymous variant in the *ectodysplasin A receptor* (*EDAR*) gene, which is associated with several traits including hair and tooth morphologies (Fujimoto et al., 2008a, b; Kimura et al., 2009; Park et al., 2012; Kamberov et al., 2013; Tan et al., 2013), shows highly different frequencies between mainland Japanese and the Ryukyuans (Yamaguchi-Kabata et al., 2008). Therefore, the *EDAR* variant is one of the candidates possibly associated with facial characteristics differentiated between the two populations. Further genetic analyses are needed to elucidate genotype–phenotype associations and genetic factors explaining facial characteristics in each population.

This study quantitatively identified differences in the facial morphology between Okinawa Islanders and mainland Japanese using 3D digital images, with special emphases on the differences in the nasal height and the prominence of the glabella and nasal root. These measurements can efficiently distinguish between the two populations. However, the present study was based only on landmarks and discarded a lot of other information contained in facial surface images. Therefore, more detailed 3D morphological analyses utilizing a large number of surface points are required to fully grasp the differences in facial features of individuals and populations. One of the solutions will be to apply homologous modeling in which semi-landmarks homologous among different faces are generated (Cheung et al., 2011; Hammond and Suttie 2012; Luximon et al., 2012). Such analysis of complicated 3D facial shapes will contribute to future studies on facial variation not only in anthropology but also in other scientific fields such as genetics, developmental biology, cognitive science, and human engineering.

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Literature cited

von Baelz E. 1911. Die Riu-Kiu-Insulaner, die Aino und andere kaukasier-ahnliche Reste in Ostasien. Korrespondenz-Blatt der Deutschen Gesellschaft fur Anthropologie. Ethnologie und Urgeschichte. 42:187-191.

Brace CL, Nagai M. 1982. Japanese tooth size: past and present. Am J Phys Anthropol 59(4):399-411.

Brace CL, Nelson AR, Seguchi N, Oe H, Sering L, Pan QF, Li YY, Tumen D. 2001. Old World sources of the first New World human inhabitants: A comparative craniofacial view. PNAS 98(17):10017-10022.

Brown P. 1999.The First Modern East Asians?: Another Look at Upper Cave 101, Liujiang and Minatogawa 1. Interdisciplinary Perspectives on the Origins of the Japanese: International Research Center for Japanese Studies. p 105-130.

Cheung LK, Chan YM, Jayaratne YS, Lo J. 2011. Three-dimensional cephalometric norms of Chinese adults in Hong Kong with balanced facial profile. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 112(2):e56- e73.

DeBruine LM, Jones BC, Smith FG, Little AC. 2010. Are attractive men's faces masculine or feminine? The importance of controlling confounds in face stimuli. J Exp Psychol Hum Percept Perform 36(3):751-758.

Dodo Y, Doi N, Kondo O. 2000. Flatness of facial skeletons of Ryukyuans. Anthropol Sci 108(2):183-198.

Doi N. 2003. Population history of the Ryukyuans as vied from skeletal morphology. In: Okinawa Prefectural Culture Promotion Foundation, editor. Okinawa Prefecture History, Archaeology. Okinawa: Okinawa Prefectural Board of Education. p 575-610.

Farkas LG, Katic MJ, Forrest CR, Alt KW, Bagic I, Baltadjiev G, Cunha E, Cvicelová M, Davies S, Erasmus I, Gillett-Netting R, Hajnis K, Kemkes-Grottenthaler A, Khomyakova I, Kumi A, Kgamphe JS, Kayo-daigo N, Le T, Malinowski A, Negasheva M, Manolis S, Ogetürk M, Parvizrad R, Rösing F, Sahu P, Sforza C, Sivkov S, Sultanova N, Tomazo-Ravnik T, Tóth G, Uzun A, Yahia E. 2005. International anthropometric study of facial morphology in various ethnic groups/races. J Craniofac Surg 16(4):615-646.

Ferrario VF, Dellavia C, Serrao G, Sforza C. 2005. Soft tissue facial angles in Down's syndrome subjects: a three-dimensional non-invasive study. Eur J Orthod 27(4):355-362.

Fujimoto A, Kimura R, Ohashi J, Omi K, Yuliwulandari R, Batubara L, Mustofa MS, Samakkarn U, Settheetham-Ishida W, Ishida T, Morishita Y, Furusawa T, Nakazawa M, Ohtsuka R, Tokunaga K. 2008a. A scan for genetic determinants of human hair morphology: EDAR is associated with Asian hair thickness. Hum Mol Genet 17(6):835-843.

Fujimoto A, Ohashi J, Nishida N, Miyagawa T, Morishita Y, Tsunoda T, Kimura R, Tokunaga K. 2008b. A replication study confirmed the EDAR gene to be a major contributor to population differentiation regarding head hair thickness in Asia. Hum Genet 124(2):179-185.

Fukase H, Wakebe T, Tsurumoto T, Saiki K, Fujita M, Ishida H. 2012. Facial characteristics of the prehistoric and early-modern inhabitants of the Okinawa islands in comparison to the contemporary people of Honshu. Anthropol Sci 120(1):23-32.

Hammond P, Suttie M. 2012. Large-scale objective phenotyping of 3D facial morphology. Hum Mutat 33(5):817-825.

Hanihara K. 1991. Dual structure model for the population history of the Japanese. Japan Review 2:1-33.

Hanihara T. 2000. Frontal and facial flatness of major human populations. Am J Phys Anthropol 111(1):105-134.

Hanihara T, Ishida H. 2009. Regional Differences in Craniofacial Diversity and the Population History of Jomon Japan. Am J Phys Anthropol 139(3):311-322.

Horai S, Murayama K, Hayasaka K, Matsubayashi S, Hattori Y, Fucharoen G, Harihara S, Park K, Omoto K, Pan I. 1996. mtDNA polymorphism in East Asian populations, with special reference to the peopling of Japan. Am J Hum Genet 59(3):579-590.

Hsu H. 1948. Anthropologische Untersuchungen uber die Riukiu-Islander. Bulletin of the Anatomical Department of the National Taiwan University 2:227-330.

HUGO Pan-Asian SNP Consortium, Abdulla MA, Ahmed I, Assawamakin A, Bhak J, Brahmachari SK, Calacal GC, Chaurasia A, Chen CH, Chen J, Chen YT, Chu J, Cutiongco-de la Paz EM, De Ungria MCA, Delfin FC, Edo J, Fuchareon S, Ghang H, Gojobori T, Han J, Ho SF, Hoh BP, Huang W, Inoko H, Jha P, Jinam TA, Jin L, Jung J, Kangwanpong D, Kampuansai J, Kennedy GC, Khurana P, Kim HL, Kim K, Kim S, Kim WY, Kimm K, Kimura R, Koike T, Kulawonganunchai S, Kumar V, Lai PS, Lee JY, Lee S, Liu ET, Majumder PP, Mandapati KK, Marzuki S, Mitchell W, Mukerji M, Naritomi K, Ngamphiw C, Niikawa N, Nishida N, Oh B, Oh S, Ohashi J, Oka A, Ong R, Padilla CD, Palittapongarnpim P, Perdigon HB, Phipps ME, Png E, Sakaki Y, Salvador JM, Sandraling Y, Scaria V, Seielstad M, Sidek MR, Sinha A, Srikummool M, Sudoyo H, Sugano S, Suryadi H, Suzuki Y, Tabbada KA, Tan A, Tokunaga K, Tongsima S, Villamor LP, Wang E, Wang Y, Wang H, Wu JY, Xiao H, Xu S, Yang JO, Shugart YY, Yoo HS, Yuan W, Zhao G, Zilfalil BA, Indian Genome Variation Consortium. 2009. Mapping human genetic diversity in Asia. Science 326:1541-1545

Hylander WL. 1977. The adaptive significance of Eskimo craniofacial morphology. In: Dahlberg A A, Graber T M, editor. Orofacial growth and development. Paris: Mouton Publishers. 129-169 p.

Ishida H. 1992. Flatness of facial skeletons in Siberian and other circum-Pacific populations. Z Morphol Anthropol 79(1):53-67.

Japanese Archipelago Human Population Genetics Consortium, Jinam T, Nishida N, Hirai M, Kawamura S, Oota H, Umetsu K, Kimura R, Ohashi J, Tajima A, Yamamoto T, Tanabe H, Mano S, Suto Y, Kaname T, Naritomi K, Yanagi K, Niikawa N, Omoto K, Tokunaga K, Saitou N. 2012. The history of human populations in the Japanese Archipelago inferred from genome-wide SNP data with a special reference to the Ainu and the Ryukyuan populations J Hum Genet 57(12):787-795.

Kamberov YG, Wang S, Tan J, Gerbault P, Wark A, Tan L, Yang Y, Li S, Tang K, Chen H, Powell A, Itan Y, Fuller D, Lohmueller J, Mao J, Schachar A, Paymer M, Hostetter E, Byrne E, Burnett M, McMahon AP, Thomas MG, Lieberman DE, Jin L, Tabin CJ, Morgan BA, Sabeti PC. 2013. Modeling recent human evolution in mice by expression of a selected EDAR variant. Cell 152(4):691-702.

Kamminga J. 1992. New interpretations of the Upper Cave, Zhoukoudian. In: Akazawa T, Aoki K, Kimura T, editor. Tokyo: Hokusen-sha. 379–400 p.

Kau CH, Zhurov A, Bibb R, Hunter L, Richmond S. 2005. The investigation of the changing facial appearance of identical twins employing a three-dimensional laser imaging system. Orthod Craniofac Res 8(2):85-90.

Kimura R, Yamaguchi T, Takeda M, Kondo O, Toma T, Haneji K, Hanihara T, Matsukusa H, Kawamura S, Maki K, Osawa M, Ishida H, Oota H. 2009. A common variation in EDAR is a genetic determinant of shovel-shaped incisors. Am J Hum Genet 85(4):528-535.

Knussmann R. 1988. Handbuch der vergleichenden Biologie des Menschen I. Anthropologie. Stuttgart: G. Fisher Verlag.

Koganebuchi K, Matsumura T, Nakagome S, Ishida H, Kawamura S, Oota H, The Asian Archival DNA Repository Consortium. 2012. Autosomal and Y-chromosomal STR markers reveal a close relationship between Hokkaido Ainu and Ryukyu islanders. Anthropol Sci 120(3):199-208.

Little AC, Jones BC, DeBruine LM. 2011. Facial attractiveness: evolutionary based research. Philos Trans R Soc Lond B Biol Sci 366:1638-1659.

Liu F, van der Lijn F, Schurmann C, Zhu G, Chakravarty MM, Hysi PG, Wollstein A, Lao O, de Bruijne M, Ikram MA van der Lugt A, Rivadeneira F, Uitterlinden A G, Hofman A, Niessen W J, Homuth G, de Zubicaray G, McMahon K L, Thompson P M, Daboul A, Puls R, Hegenscheid K, Bevan L, Pausova Z, Medland S E, Montgomery G W, Wright M J, Wicking C, Boehringer S, Spector T D, Paus T, Martin N G, Biffar R, Kayser M. 2012. A genome-wide association study identifies five loci influencing facial morphology in Europeans. PLoS Genet 8(9):e1002932.

Luximon Y, Ball R, Justice L. 2012. The 3D Chinese head and face modeling. Computer-Aided Design 44(1):40-47.

Matsukusa H, Oota H, Haneji K, Toma T, Kawamura S, Ishida H. 2010. A genetic analysis of the Sakishima Islanders reveals no relationship with Taiwan Aborigines but shared ancestry with Ainu and Main-Island Japanese. Am J Phys Anthropol 142(2):211-223.

Miyake M. 1940. Anthropometry of the Japanese. Anthropological and Prehistoric courses. Tokyo: Yuzankaku. p1-69

Mori N, Terashima M, Tokumori K, Nakashima A, Aoki Y, Hashimoto S. 2003. Head bioinstrumentation and construction of face standard three-dimensional physical model of modern Japanese adults of both sexes using three-dimensional CT images. Anthropol Sci Jap Series 111(1):35-49.

Naito Y. 1976. The Okinawa Islanders viewed from anthropolometric measurements. In: Kyugakkai-Rengo, editor. Okinawa:Nature, Culture, and Society. Tokyo: Kobundo. p 77-86.

Nakata M, Yu PL, Davis B, Nance WE. 1974. Genetic determinants of cranio-facial morphology: a twin study. Ann Hum Genet 37(4):431-443.

Omoto K, Saitou N. 1997. Genetic origins of the Japanese: A partial support for the dual structure hypothesis. Am J Phys Anthropol 102(4):437-446.

Park JH, Yamaguchi T, Watanabe C, Kawaguchi A, Haneji K, Takeda M, Kim YI, Tomoyasu Y, Watanabe M, Oota H, Hanihara T, Ishida H, Maki K, Park SB, Kimura R. 2012. Effects of an Asian-specific nonsynonymous EDAR variant on multiple dental traits. J Hum Genet 57(8):508-514.

Paternoster L, Zhurov AI, Toma AM, Kemp JP, St Pourcain B, Timpson NJ, McMahon G, McArdle W, Ring SM, Smith GD, Richmond S, Evans DM. 2012. Genome-wide association study of three-dimensional facial morphology identifies a variant in PAX3 associated with nasion position. Am J Hum Genet 90(3):478-485.

Penton-Voak IS, Perrett DI, Castles DL, Kobayashi T, Burt DM, Murray LK, Minamisawa R. 1999. Menstrual cycle alters face preference. Nature

399(6738):741-742.

Pietrusewsky M. 1999. A multivariate craniometric study of the Ryukyu Islanders and their relationship with the prehistoric and modern peoples of Japan, Asia, and the Pacific. Anthropol Sci 107(4):255-281.

Pietrusewsky M. 2004. Multivariate comparisons of female cranial series from the Ryukyu Islands and Japan. Anthropol Sci 112(3):199-211.

Steegmann AT, Cerny FJ, Holliday TW. 2002. Neandertal cold adaptation: physiological and energetic factors. Am J Hum Biol 14(5):566-583.

Suda A. 1940. Anthropometric measurements of the Ryukyu Islanders. J Anthropol Soc Nippon 55(2):39-63.

Suda A. 1950. The physical anthropology of the Ryukyuans. Minzokugaku-Kenkyu. 109-116.

Suzuki H. 1981. Racial history of the Japanese. In: Schwidetzky I, editor. Rassengeschichte der menschheit. Munchen: R. Oldenbourg Verlag. p 7-69.

Tan J, Yang Y, Tang K, Sabeti PC, Jin L, Wang S. 2013. The adaptive variant EDARV370A is associated with straight hair in East Asians. Hum Genet 132(10):1187-1191.

Toma A, Zhurov A, Playle R, Marshall D, Rosin P, Richmond S. 2012. The assessment of facial variation in 4747 British school children. Eur J Orthod 34(6):655-664.

Tomoyose E, Higa A, Sakai H, Sawaguchi S, Iwase A, Tomidokoro A, Amano S, Araie M. 2010. Intraocular pressure and related systemic and ocular biometric factors in a population-based study in Japan: The Kumejima study. Am J Ophthalmol 150(2):279-286.

Vezzetti E, Marcolin F. 2012. 3D human face description: landmarks measures and geometrical features. Image Vis Comput 30(10):698-712.

Watanabe T, Saiki K, Okamoto K, Wakebe T. 2004. Metrical and nonmetrical analyses of modem female crania in the northwestern Kyushu area. Anthropol Sci 112(2):147-159.

Yamaguchi B. 1973. Facial flatness measurements of the Ainu and Japanese crania. Bull Natn Sci Mus 16:161-171.

Yamaguchi B. 1982. A review of the osteological characteristics of the Jomon population in prehistoric Japan: J Anthropol Soc Nippon 90(Suppl):77-90.

Yamaguchi-Kabata Y, Nakazono K, Takahashi A, Saito S, Hosono N, Kubo M, Nakamura Y, Kamatani N. 2008. Japanese population structure, based on SNP genotypes from 7003 individuals compared to other ethnic groups: effects on population-based association studies. Am J Hum Genet 83(4):445-456.

Table 1. Characteristics of the study participants.

	Male			Female		
	Mainland Japanese	Okinawa Islanders	*P*-value	Mainland Japanese	Okinawa Islanders	*P*-value
N	30	30		30	30	
Age	23.7	22.3	-	24.4	22.4	-
	(20~32)	(19~28)		(20~37)	(19~36)	
Body Height±SD	171.4 ± 5.1	168.6 ± 4.3	**2.5E-02**	159.4 ± 4.8	156.2 ± 4.3	**8.5E-03**
(cm)	(158.6~182.4)	(160.0~176.1)		(148.5~169.5)	(145.7~164.5)	
Body Weight±SD	65.8 ± 7.1	63.6 ± 6.8	0.23	53.2 ± 8.5	51.9 ± 5.9	0.48
(kg)	(51.0~83.6)	(44.5~77.0)		(42.6~85.3)	(39.2~62.1)	
BMI±SD	22.4 ± 2.3	22.4 ± 2.3	0.95	20.9 ± 2.6	21.3 ± 2.3	0.50
	(18.6~29.4)	(17.4~27.8)		(17.1~30.8)	(16.9~25.1)	

Ranges are shown in the parentheses. **Bold:** $P < 0.05$.

Table 2. Abbreviations of landmarks.

Part	Abb.	Landmarks	M or R/L
Forehead	G	Glabella	M
	Se	Sellion	M
Eyes	En	Entocanthion	R/L
	Ex	Ectocanthion	R/L
Nose	Prn	Pronasale	M
	Sn	Subnasale	M
	Ac	Alar curvature	R/L
Cheeks	Zy	Zygion	R/L
	Cdl	Condylion laterale	R/L
Mouth	Chl	Chellion	R/L
	Ls	Labrale superius	M
	Li	Lablare inferius	M
Chin	Sgn	Supragnathion	M
Jaw	Go	Gonion	R/L

M: Midline; R: Right; L: Left.

Table 3. Regional differences of facial measurements.

			Male					Female					Combined
			Mainland Japanese		Okinawa Islanders		Regional Difference	Mainland Japanese		Okinawa Islanders		Regional Difference	Regional Difference
Measurements			Mean	SD	Mean	SD	*P*-value	Mean	SD	Mean	SD	*P*-value	*P*-value
Height	1	G-Se	21.0	3.6	21.2	2.3	0.84	20.1	3.6	19.6	2.9	0.57	0.80
	2	G-Sgn	140.0	7.9	135.9	5.4	**2.4E-02**	133.5	6.6	128.3	5.7	**1.9E-03**	**1.5E-04**
	3	Se-Sn	53.7	2.2	50.0	3.5	**1.0E-05**	50.3	2.6	47.8	3.1	**1.2E-03**	**6.0E-08**
	4	Sn-Sgn	67.7	5.8	66.7	4.2	0.46	65.2	4.5	62.7	3.9	**2.6E-02**	**3.6E-02**
Breadth	5	En-En	40.4	3.4	40.3	3.1	0.91	39.1	2.2	39.4	2.6	0.55	0.74
	6	Ex-Ex	99.7	4.3	97.8	4.5	0.09	97.9	4.5	95.8	4.3	0.06	**1.2E-02**
	7	Zy-Zy	149.4	5.6	147.9	6.7	0.34	143.4	5.3	143.0	5.0	0.75	0.37
	8	Cdl-Cdl	151.9	5.4	151.1	6.8	0.62	143.4	5.0	142.1	5.5	0.36	0.32
	9	Ac-Ac	39.1	2.2	38.2	2.3	0.14	36.2	2.1	36.2	2.1	0.90	0.26
	10	Chl-Chl	47.2	3.0	47.3	2.9	0.90	43.7	3.4	44.0	3.8	0.75	0.75
	11	Go-Go	123.8	8.8	120.9	7.7	0.18	115.0	5.5	111.9	7.7	0.08	**2.8E-02**
Depth	12	En(m)-Cdl(m)	81.4	4.5	80.6	3.7	0.45	80.1	3.2	77.8	4.1	**2.3E-02**	**3.3E-02**
	13	Ac(m)-Cdl(m)	84.8	4.4	84.8	5.0	1.00	81.0	4.4	79.6	3.9	0.20	0.37
	14	Ls-Cdl(m)	104.8	4.7	104.6	5.2	0.86	98.0	5.8	96.9	4.2	0.40	0.47
	15	Sgn-Cdl(m)	118.2	5.6	117.7	6.6	0.75	110.8	7.9	109.4	5.8	0.43	0.43
	16	G-RP	14.8	2.3	17.8	1.7	**5.0E-07**	11.0	2.1	12.7	2.1	**2.0E-03**	**1.2E-08**
	17	Se-RP	9.3	1.7	10.8	1.8	**1.2E-03**	6.6	1.6	7.6	1.7	**2.7E-02**	**1.2E-04**
	18	Prn-RP	25.7	2.1	25.0	2.2	0.21	22.1	1.9	22.3	1.9	0.70	0.54
	19	Sn-RP	9.7	2.2	9.4	1.6	0.56	8.0	1.7	8.0	1.4	0.99	0.69
	20	Ls-RP	11.2	2.9	11.0	2.5	0.72	10.2	2.4	10.6	2.2	0.48	0.80
	21	Li-RP	5.2	4.7	4.8	3.8	0.73	5.9	2.9	5.6	3.6	0.66	0.58
	22	Sgn-RP	-14.5	7.4	-14.4	5.2	0.92	-13.1	6.2	-11.9	6.6	0.48	0.57
Angle	23	G-Se-Prn	143.4	6.1	141.2	6.2	0.16	145.4	5.0	143.5	4.9	0.15	**4.5E-02**
	24	En-Se-En	125.4	8.7	121.1	8.2	5.6E-02	134.8	8.6	132.2	8.4	0.24	**2.9E-02**
	25	Gonial angle	128.0	4.6	128.1	5.9	0.90	127.7	4.9	127.2	4.2	0.68	0.84
	26	Ac(m)-Se-Prn	32.5	2.8	33.6	3.5	0.20	30.2	2.6	31.7	3.1	5.3E-02	**2.3E-02**
	27	Cdl-Se-Cdl	79.6	3.0	79.0	2.9	0.44	78.7	2.5	79.1	3.5	0.55	0.89

(m): middle point between right and left of the landmarks. Protrusion of X from Reference Plane (RP), which can take negative values (16-22). **Bold:** $P < 0.05$. Abbreviations are listed in Table 2. Measurements are shown in Figure 2.

Table 4. Principal components and loadings of measurements.

Measurements		PC1	PC2	PC3	PC4	PC5	PC6	PC7
Height	G-Se	0.27	0.22	0.35	0.03	0.56	0.12	0.30
	G-Sgn	0.65	0.00	0.29	-0.43	0.46	-0.19	-0.07
	Se-Sn	0.52	-0.27	0.06	-0.25	-0.10	-0.62	-0.26
	Sn-Sgn	0.46	0.02	0.17	-0.53	0.46	0.05	-0.24
Breadth	En-En	0.37	-0.12	0.40	0.05	0.36	0.23	0.14
	Ex-Ex	0.61	0.08	0.52	0.03	-0.04	-0.05	-0.11
	Zy-Zy	0.71	0.03	0.33	0.46	-0.07	-0.13	0.12
	Cdl-Cdl	0.77	-0.02	0.17	0.46	0.01	-0.15	0.12
	Ac-Ac	0.63	-0.08	0.10	0.28	-0.04	0.07	-0.24
	Chl-Chl	0.63	-0.05	-0.10	0.26	0.07	-0.02	-0.05
	Go-Go	0.70	-0.12	0.18	0.40	-0.04	-0.05	-0.03
Depth	En(m)-Cdl(m)	0.63	-0.31	0.31	-0.35	-0.38	0.22	0.05
	Ac(m)-Cdl(m)	0.74	-0.45	0.03	-0.14	-0.36	0.23	0.05
	Ls-Cdl(m)	0.87	-0.17	-0.05	-0.16	-0.28	0.17	0.03
	Sgn-Cdl(m)	0.83	0.09	0.02	-0.12	-0.23	0.06	0.17
	G-RP	0.54	-0.16	-0.58	0.28	0.27	0.33	0.09
	Se-RP	0.53	-0.22	-0.70	0.05	0.23	0.00	0.28
	Prn-RP	0.66	0.40	-0.44	-0.13	0.05	-0.21	-0.23
	Sn-RP	0.42	0.65	-0.33	-0.22	-0.05	-0.18	-0.09
	Ls-RP	0.33	0.81	0.08	-0.29	-0.06	0.01	0.03
	Li-RP	0.07	0.84	0.20	-0.27	-0.11	0.04	0.16
	Sgn-RP	0.00	0.71	0.13	0.12	-0.42	-0.06	0.39
Angle	G-Se-Prn	-0.13	-0.37	0.12	-0.34	0.12	-0.54	0.55
	En-Se-En	-0.37	0.18	0.81	0.05	0.00	0.25	-0.18
	Gonial angle	0.06	-0.04	0.07	-0.32	0.27	0.29	0.18
	Ac(m)-Se-Prn	0.30	0.70	-0.43	0.06	0.12	0.21	-0.08
	Cdl-Se-Cdl	-0.07	0.36	0.21	0.75	0.26	-0.28	-0.05
Eigenvalue		7.79	3.80	3.07	2.54	1.78	1.43	1.08
Contribution (%)		28.9	14.1	11.4	9.4	6.6	5.3	4.0

(m): middle point between right and left of the landmarks. RP: Reference Plane.

Table 5. Multiple regression analyses for principal component scores.

	Sex			Region			Body Height (cm)			Body Mass Index			Constant
	B	*β*	*P*	*B*	*β*	*P*	*B*	*β*	*P*	*B*	*β*	*P*	
PC1	-2.20	-0.39	**1.5E-05**	-0.24	-0.043	0.43	0.11	0.32	**4.7E-04**	0.39	0.34	**4.0E-09**	-25.97
PC2	0.11	0.028	0.86	0.34	0.090	0.36	0.012	0.049	0.76	-0.071	-0.090	0.36	-0.71
PC3	1.49	0.43	**2.2E-03**	-1.12	-0.32	**2.9E-04**	0.017	0.075	0.59	0.16	0.23	**8.7E-03**	-6.43
PC4	-1.04	-0.33	**3.1E-02**	0.42	0.13	0.17	-0.060	-0.29	0.056	0.080	0.12	0.19	8.34
PC5	-1.09	-0.41	**7.6E-03**	0.077	0.029	0.76	-0.032	-0.19	0.22	-0.11	-0.20	**3.5E-02**	8.17
PC6	-0.52	-0.22	0.13	0.71	0.30	**1.3E-03**	-0.048	-0.31	**3.4E-02**	-0.014	-0.028	0.75	8.05
PC7	0.42	0.20	0.18	0.48	0.23	**1.6E-02**	0.015	0.11	0.45	0.076	0.18	0.060	-4.61

Sex: Male=0, Female=1. Region: Mainland Japan=0, Okinawa Island=1. *B*: partial regression coefficient. *β*: standardized partial regression coefficient. **Bold:** $P < 0.05$.

Table 6. Discriminant analysis of the measurements.

	27 measurements		Stepwise		
	Accuracy (%)	Accuracy (%) (Cross-validated)	Accuracy (%)	Accuracy (%) (Cross-validated)	Remaining independent variables
Male& Female	80.0	70.8	77.5	77.5	Se-Sn G-RP
Male	91.7	60.0	80.0	80.0	Se-Sn G-RP
Female	85.0	55.0	70.0	66.7	Se-Sn G-RP

Figure legends

Figure 1. Position of the 21 landmarks. Front view (a) and lateral view (b). Fourteen bilateral landmarks and seven landmarks on the midline were plotted according to those defined by Martin (Knussmann, 1988).

Figure 2. Definition of the 27 measurements used in this study. Heights (a), breadths (b and c), and angles (c and d). The reference plane (RP) was defined by the three landmarks: the right Ac, the left Ac, and the midentocanthion, En(m) (e). The depths and the protrusions of landmarks on the mid-sagittal plane from RP (f). The measured values are listed in Table 3.

Figure 3. Loadings of PC1, PC2, and PC3.

Figure 4. Scatter diagrams of the PC scores. PC1 vs PC2 (a) and PC1 vs PC3 (b). A cross symbol represents the centroid for each group. Extracted facial images are extreme examples for each PC.

Figure 5. Variation in the position of the sellion. Facial features of representative individuals with a high PC2 score (a) and a low PC2 score (b). A negative correlation was observed between G-Se/G-Sn and Se-RP/G-RP (c).

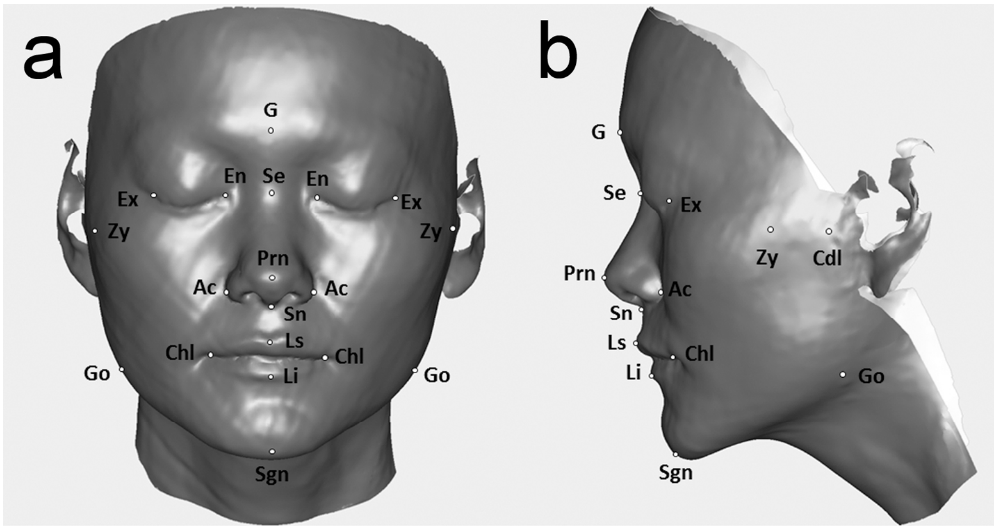

Figure 1. Position of the 21 landmarks. Front view (a) and lateral view (b). Fourteen bilateral landmarks and seven landmarks on the midline were plotted according to those defined by Martin (Knussmann, 1988).
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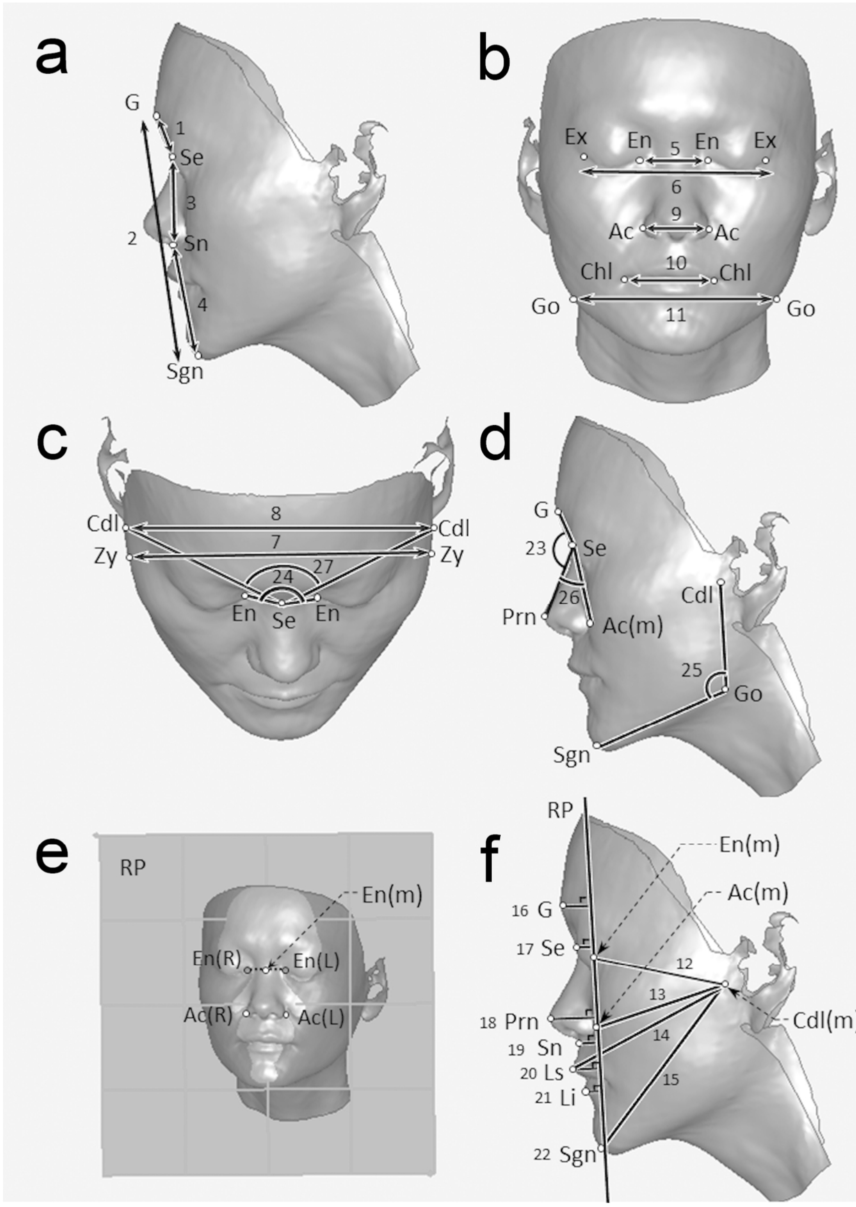

Figure 2. Definition of the 27 measurements used in this study. Heights (a), breadths (b and c), and angles (c and d). The reference plane (RP) was defined by the three landmarks: the right Ac, the left Ac, and the midentocanthion, En(m) (e). The depths and protrusion of each landmark on the mid-sagittal plane from RP (f). The measured values are listed in Table 3.
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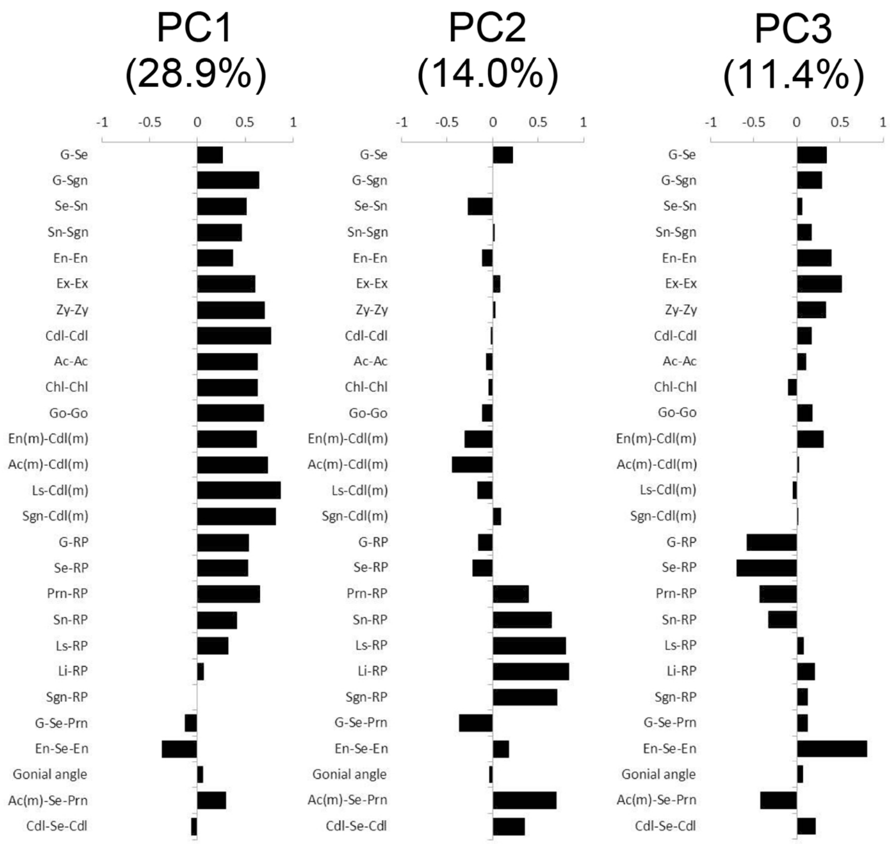

Figure 3. Loadings of PC1, PC2, and PC3.
139x124mm (300 x 300 DPI)

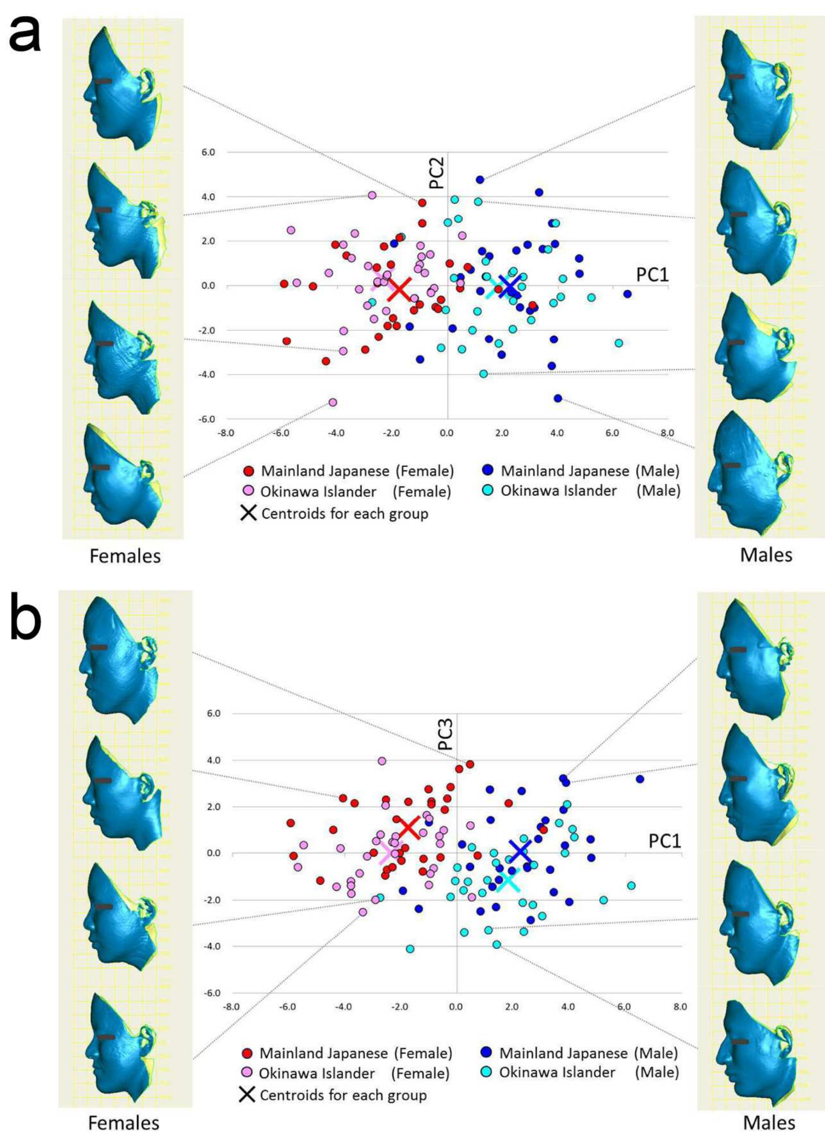

Figure 4. Scatter diagrams of the PC scores. PC1 vs PC2 (a) and PC1 vs PC3 (b). A cross symbol represents the centroid for each group. Extracted facial images are extreme examples for each PC.
139x194mm (300 x 300 DPI)

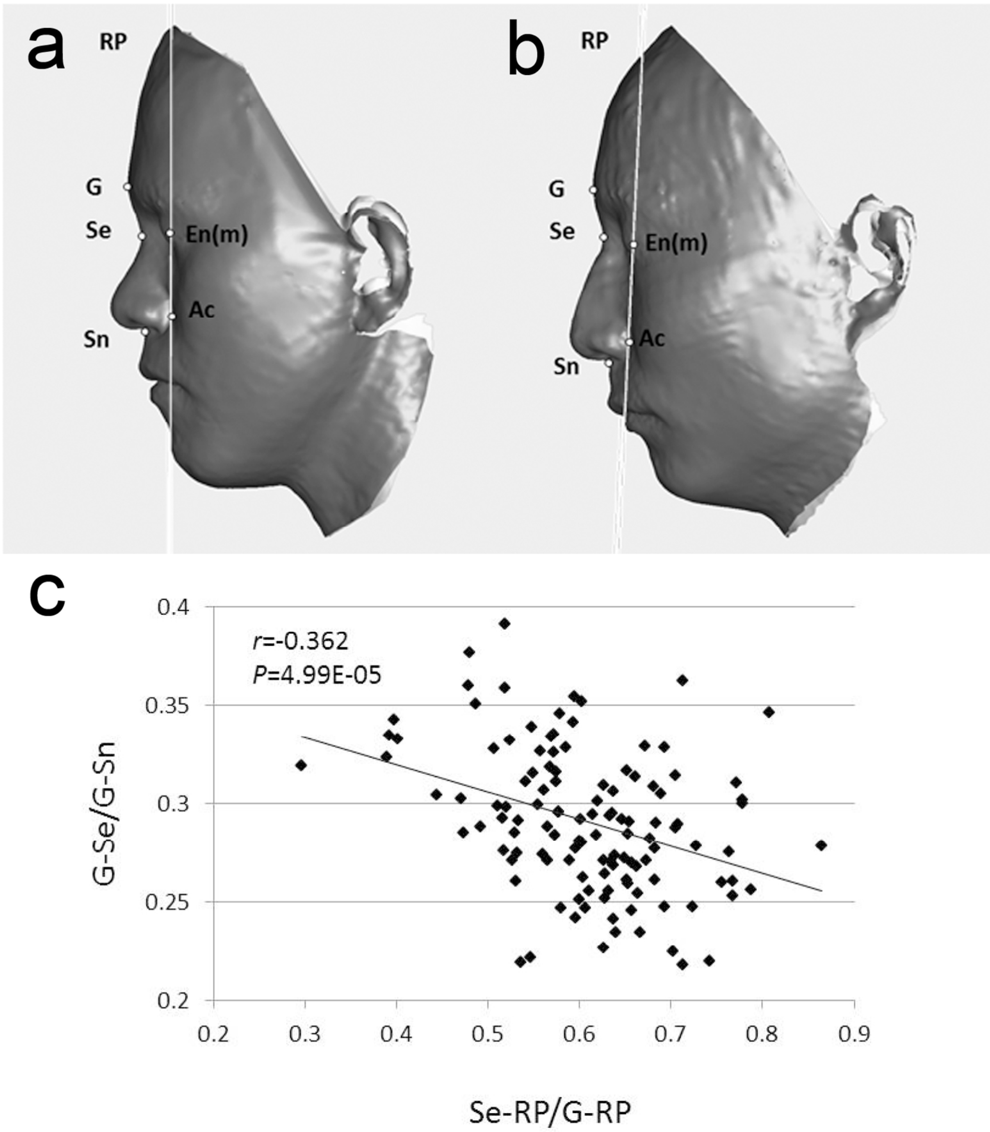

Figure 5. Variation in the position of the sellion. Facial features of representative individuals with a high PC2 score (a) and a low PC2 score (b). A negative correlation was observed between G-Se/G-Sn and Se-RP/G-RP (c).
139x160mm (300 x 300 DPI)