Angular Asymmetries of the Human Face

Sunphat Namano, DDS (Chula), Grad Dip (Chula), Grad Dip (Melb), MDSc (Melb)[a]
Donald A. Behrend, MDSc (Melb), BSc (Melb), PhD (Melb), FRACDS[b]
John K. Harcourt, OAM, DDSc (Melb), FRACDS, FDSRCSEd (Hon)[c]
Peter R. Wilson, MDS (Newcastle), MS (Minn), PhD (Melb), FDSRCSEd, DRDRCSEd[d]

Purpose: The determination of an acceptable occlusal plane is essential for the development of esthetic prosthodontic restorations. However, since most faces are not symmetric, a method was developed for measuring facial angular asymmetry, ie, the divergence from the vertical or horizontal of the line joining the midpoint of the intercanthal line and the philtrum of the lip, the interpupillary line, the intermeatal line, the lip commissure line, and the intercuspid line. **Materials and Methods:** Standardized frontal images (mouth closed, smiling, and biting on a wooden spatula) of 100 subjects were taken using a digital camera. These images were downloaded into a computer, and the angles between the various facial lines and the horizontal were measured. The subjects were grouped by sex, age, and history of trauma and orthodontic treatment. **Results:** No statistically significant differences were found between the mean values for each group. **Conclusion:** Asymmetry of the face can be measured using digital camera imaging and computer analysis. A range of facial asymmetries that can influence the choice of occlusal plane during prosthodontic treatment exists. Thus, the use of an occlusal plane parallel to the ala tragus and interpupillary lines, as often advocated by prosthodontists, may result in less than ideal esthetics in the final restoration.
Int J Prosthodont 2000;13:41–46.

A number of studies on facial asymmetry have been reported,[1–12] each with defined materials and methods to meet specific objectives. Some studies have attempted to explain the etiology of the asymmetries or to identify a zone of acceptability for normal asymmetry of the face. Clinical treatment has been improved by the application of results from these studies.

Biologic structures in vertebrates develop according to a general symmetric pattern, but during growth and development the 2 halves partially modify their basic design, and various degrees of asymmetry develop in different organs and features. Structural asymmetry can be further modified by function, trauma, or disease.[13–21] There are always asymmetries of the human face, even in those who have been judged to be "beautiful."[22,23] The challenge for the prosthodontist is to determine which reference plane can be used as a guide for alignment of the maxillary anterior teeth in cases that require their replacement or extensive restoration.

This study used an inexpensive and standardized digital photographic technique to measure angular asymmetries of the human face; the results may be applicable to clinical practice.

[a]*Formerly, Graduate Student, School of Dental Science, The University of Melbourne, Victoria, Australia; Currently, Department of Prosthodontics, Faculty of Dentistry, Chulalongkorn University, Bangkok, Thailand.*
[b]*Specialist Prosthodontist, Melbourne, Victoria, Australia.*
[c]*Honorary Principle Fellow, School of Dental Science, The University of Melbourne, Victoria, Australia.*
[d]*Associate Professor, School of Dental Science, The University of Melbourne, Victoria, Australia.*

Reprint requests: *Dr P. R. Wilson, School of Dental Science, 711 Elizabeth Street, Melbourne, Victoria, Australia 3000. Fax: + 613/03 9341 0437. e-mail: p.wilson@dent.unimelb.edu.au*

This work is based on a thesis submitted to the School of Dental Science, The University of Melbourne, by Dr Namano in partial fulfillment of the requirements for the Master of Dental Science degree.

Materials and Methods

One hundred subjects were recruited randomly from among dental students and staff at the Royal Dental Hospital of Melbourne. The mean age of the subjects was 33.6 years (standard deviation [SD] 12.6, range 19 to 67). There were 38 men and 62 women; 71 subjects were Caucasian and 29 were Asian. There was a history of orthodontic treatment and/or trauma to the face in 32 of the 100 subjects. All subjects could be categorized as having a normal appearance, without obvious deformities.

The objectives and methods of obtaining the photographs for the project were explained to each subject, and each read and signed a consent form prior to joining the program. The project was approved by the Human Ethics Committee of the Royal Dental Hospital of Melbourne.

Photographic Technique

This project used a Kodak Digital Science DC50 camera (Eastman Kodak), which stores photographic images digitally for later transfer to a computer. The 33 motorized zoom lens has an autofocus range in normal mode of 29 in (737 mm) to infinity. The camera's 1 Mb of internal memory allows the storage of 7 images with a resolution of 756 3 504 pixels, which is sufficient for computer analysis.

A small rectangular mirror was attached to the top of the camera such that the lower border of the mirror was horizontal. In the middle area on top of the camera, a bubble gauge spirit level was attached. The camera was placed on a standard adjustable tripod mount. The tripod arms and adjustable plates were set so that the camera was horizontal.

Each subject was asked to stand on footprints drawn on the floor 1,500 mm in front of the camera and to look straight ahead. The camera was adjusted up or down vertically without tilting, depending on the subject's height, until the subject saw his or her interpupillary line level with the lower border of the mirror attached to the top of the camera. This ensured that the level of each subject's eyes was constant in relation to the lens and the camera flash. A Hanau Spring-Bow facebow (Teledyne Water Pik) fitted with pointers in the outer aspect of the ear rods was inserted into the subject's external auditory meati (Figs 1 to 3). A plumb line hanging beside the subject acted as the vertical reference line.

Setting the built-in flash to the "always on" mode ensured that its reflection could be detected in the subjects' pupils in every image because they were asked to look straight toward the camera. As the patients' eyes were focused at the same level, the outermost convexity of the eyeball reflected the flash.

Three frontal view images were taken for each subject: *(1)* mouth closed, *(2)* smiling, and *(3)* biting on a disposable wooden spatula passing as a straight edge between the maxillary canines. The three color images were downloaded from the digital camera into a computer. (Either Macintosh or IBM-type computers can be used.) Each image was then converted to gray scale and saved onto the computer's hard disk.

Angles

Using CorelDRAW, version 4.00 (Corel), the 3 grayscale images from each subject were analyzed and landmark points were located. The position of each landmark was digitized on the computer as a set of pixel coordinates (x, y). On each image, the upper and lower points of the plumb line were identified and digitized, and a line was drawn between them. A line at a right angle to this was taken as the true horizontal, and this was used as the reference against which the angles of the facial lines were calculated on the computer.

The following facial lines were drawn on the 3 images and their angles calculated.

- Image 1 (mouth closed)
  - Interpupillary line (IP): line joining the reflection points of the camera's flash on the pupils of the subject's eyes.
  - Intermeatal line (IM): line joining the tips of the pointers on the ear rods of the Hanau facebow.
  - Commissure line, closed (CC): line joining the angles of the mouth with the mouth closed.
  - Facial midline (FM): line joining the midpoint of the line between the inner canthi of the eyes and the center of the philtrum of the upper lip (Fig 1).
- Image 2 (smiling)
  - Interpupillary line (IP)
  - Intermeatal line (IM)
  - Commissure line, smiling (CS): line joining the angles of the mouth while smiling (Fig 2).
- Image 3 (biting on wooden spatula)
  - Interpupillary line (IP)
  - Intermeatal line (IM)
  - Intercuspid line (IC): line joining the right and left sides of the wooden spatula in contact with the tips of the maxillary canines (Fig 3).

All measured angles were entered into the computer using a spreadsheet (Microsoft Excel). Correlations between the various angles were studied, and pairs of different angles were plotted on a scatter plot to determine whether there was any relation between the 2 variables. The Student's *t* test and analysis of variance (ANOVA) (2-tailed) were also calculated.

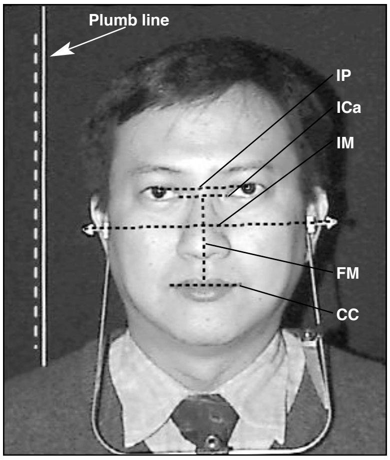

Fig 1 Closed-mouth image shows construction lines used for angular measurements. *IP* = interpupillary line; *ICa* = intercanthal line; *IM* = intermeatal line; *FM* = facial midline; *CC* = commissure line (closed).

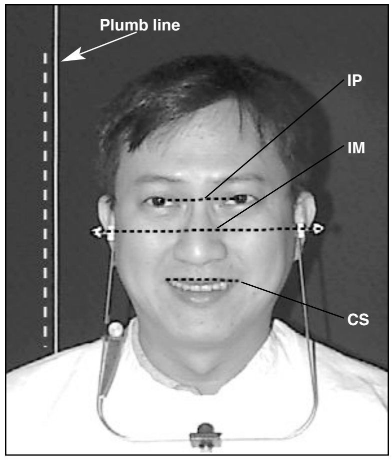

Fig 2 *(above right)* Smiling image shows construction lines. *IP* = interpupillary line; *IM* = intermeatal line; *CS* = commissure line (smiling).

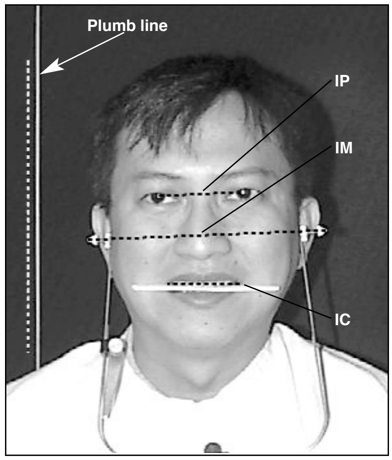

Fig 3 *(right)* Image with subject biting on a wooden spatula shows construction lines. *IP* = interpupillary line; *IM* = intermeatal line; *IC* = intercuspid line.

Reproducibility of Measurements

A test was performed to verify the accuracy of the image taken from the digital camera. The digital camera was set up perpendicular to a card on which a known angle had been drawn, and images were acquired. After downloading the images from the camera to the hard disk of the computer, measurements were made using CorelDRAW. The angles obtained from the computer matched those drawn on the card to within ± 0.1 degree.

Another test was performed prior to the actual data collection to verify the reproducibility of the system used in this project. Ten sets of three images were taken of the same subject in the three different positions: mouth closed, smiling, and biting on a wooden spatula. Six lines were drawn, and angular measurements were performed on each of the closed-mouth images. Four lines were drawn, and the angles between them were measured from each of the smiling and wooden spatula images. Each measurement was repeated three times on each image.

From the 10 closed-mouth images, 180 lines were drawn and measured. The magnitude of error was 0.1 degree or 0 for 84% of the measurements (151 of 180). Furthermore, 95% of the measurements (171 of 180) exhibited 0.2 degree or less difference. From the 10 smiling images, the error was 0.1 degree or 0 for 81% of the measurements (97 of 120) and 0.2 degree or less for 93% of the measurements (112 of 120). From the 10 biting on a wooden spatula images, the error was 0.1 degree or 0 for 85% of the measurements (102 of 120) and 0.2 degree or less for 95% of the measurements (114 of 120).

One factor that limited the accuracy of measurements was the resolution of the monitor. Although the image can be magnified to check the accuracy of a landmark, and one or both ends of a line can be changed and the resulting new angle can be remeasured, a landmark misplaced by only one pixel can introduce an error in the measurement of 0.2 degree. Despite this, 94% of the reproducibility measurements (132 of 140) were accurate to within one pixel.

Table 1 Angular Measurements (Degrees) from 3 Images from Each Subject (n = 100)

Image	Mean	SD	Range
Mouth closed			
IP	–0.3	1.1	–3.7 to 2.3
IM	0.3	1.2	–3.2 to 3.8
CC	0.2	1.8	–3.6 to 6.1
FM	89.6	1.9	83.5 to 94.5
Smiling			
IP	–0.3	1.1	–3.0 to 2.8
IM	0.2	1.2	–2.6 to 3.9
CS	–0.2	1.9	–5.4 to 7.0
Biting spatula			
IP	–0.3	1.1	–3.2 to 3.1
IM	0.2	1.3	–2.8 to 3.4
IC	–0.1	1.9	–5.2 to 5.2

IP = interpupillary line against horizontal; IM = intermeatal line against horizontal; CC = commissure line (closed) against horizontal; FM = facial midline against horizontal; CS = commissure line (smiling) against horizontal; IC = intercuspid line against horizontal.

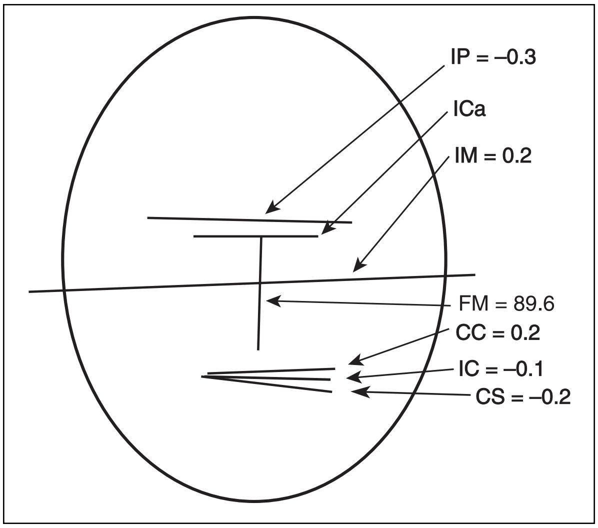

Fig 4 Mean values of the angles formed by the various construction lines against the horizontal plane (n = 100 subjects). *IP* = interpupillary line; *ICa* = intercanthal line; *IM* = intermeatal line; *FM* = facial midline; *CC* = commissure line (closed); *IC* = intercuspid line; *CS* = commissure line (smiling). (Note: angles have been exaggerated for the sake of clarity.)

Results

Total Population

The means, standard deviations, and ranges of the data of angular measurements from the 3 images of each of the 100 subjects are reported in Table 1. Positive angles are those diverging counterclockwise from the horizontal. Negative angles are those diverging clockwise from the horizontal. For the facial midline, angles greater than 90 degrees diverge counterclockwise from the vertical. Angles less than 90 degrees diverge clockwise from the vertical.

The mean intermeatal line (IM) value in Fig 1 is 0.1 degree different from the mean IM values in Figs 2 and 3. To put the data together in one figure, the average of the 3 mean IMs was calculated, with 0.2 degree being the average of these values for the 3 images. Figure 4 is a diagram representing the human face. The lines drawn inside the diagram are the mean values of the angles from the 3 images of each subject against the horizontal plane.

Male and Female Subjects

There was no significant difference between the mean values of the data of angular measurements for the male and female groups ($P > 0.4$).

Age Groups

When dividing the subjects into 3 age groups (19 to 24 years old, n = 32; 25 to 35 years old, n = 33; and 36+ years old, n = 35), there was no significant difference between the mean values of the data of angular measurements for the 3 age groups ($P > 0.1$).

Facial Trauma and/or Orthodontic Treatment

When comparing the data of angular measurements between the groups of subjects with and without a history of facial trauma and/or orthodontic treatment, the correlation coefficients between the mean values in both groups were low and there was no significant difference between the mean values of the data for the 2 groups ($P > 0.1$).

Analysis of Results

The interpupillary line (IP) was horizontal in 16% of all subjects, tilted clockwise in 50%, and tilted counterclockwise in 34%. The IC was horizontal in 18%, tilted clockwise in 47%, and tilted counterclockwise in 35%.

The mean IP angle (–0.3 degree), mean commissure line (smiling) (CS) angle (–0.2 degree), mean intercuspid line (IC) angle (–0.1 degree), and mean facial midline (FM) angle (89.6 degrees) were all clockwise, while the mean IM (0.3 degree) was counterclockwise.

The Pearson's correlation coefficients between IP and IC and between IM and IC were low ($r < 0.4$). Hence, the tilts of the IP, IM, and IC were not dependent on each other and could therefore not be used to predict each other.

Comparing male and female subjects, the mean IP of both groups tilted clockwise (–0.3 degree). In female subjects the mean IC, CC, and CS also tilted clockwise and were nearly parallel to the mean IP, but the mean IM tilted slightly counterclockwise (0.1 to 0.2 degree). In males, the mean IC and IM tilted counterclockwise and were approximately parallel (0.4 degree). The mean CC tilted further counterclockwise (0.7 degree), but the mean CS was almost horizontal. However, there was no statistically significant difference between the data from the 2 groups.

Comparing the 3 age groups, there seems to be a general trend for most of the facial angles to progress from clockwise toward 0 or counterclockwise with increasing age, but again, the differences were not statistically significant.

The data for subjects with and without a history of facial trauma and/or orthodontic treatment show the IC in the unaffected group to be almost parallel to the IP, while in the affected group it was closest in angulation to the CS. The differences are small and not statistically significant, but there may be some indication that the IC line in the second group had been adjusted by surgical or orthodontic treatment toward parallelism with the CS line.

Considering ranges rather than means, all of the measured angles showed a distribution over several degrees. For example, although the IC line angulation showed a normal distribution, in only 18 subjects was it close to 0 (– 0.25 to 0.25 degree). In 73 subjects the angle was within the range from –2 to 2 degrees, in 11 subjects it was negative (clockwise) by more than 2 degrees, and in 16 subjects it was positive (counterclockwise) by more than 2 degrees. The most extreme values were more than 5 degrees in each direction. An angle of 5 degrees means that the canine tip on one side of the mouth is approximately 2.6 mm lower than on the other side.

Using the IM line rather than the horizontal as the reference against which the angles of the other lines are measured gave the results shown in Table 2. Relative to the IM, the mean IP_{IM}, CC_{IM}, FM_{IM}, CS_{IM}, IC_{IM}, and H_{IM} values were all clockwise, with mean angles of –0.6, –0.1, –0.7, –0.4, –0.3, and –0.2 degree, respectively.

Table 2 Angular Measurements (Degrees) Against Intermeatal Line from 3 Images from Each Subject (n = 100)

Image	Mean	SD	Range
Mouth closed			
IP_{IM}	–0.6	1.2	–3.5 to 2.5
CC_{IM}	–0.1	1.7	–4.0 to 4.2
FM_{IM}	89.3	1.8	84.2 to 94.8
H_{IM}	–0.3	1.2	–3.8 to 3.2
Smiling			
IP_{IM}	–0.6	1.0	–3.6 to 2.4
CS_{IM}	–0.4	1.6	–4.6 to 4.2
H_{IM}	–0.2	1.2	–3.9 to 2.6
Biting spatula			
IP_{IM}	–0.5	1.0	–3.3 to 2.4
IC_{IM}	–0.3	1.9	–4.5 to 5.2
H_{IM}	–0.2	1.3	–3.4 to 2.8

IP_{IM} = interpupillary line against intermeatal line; CC_{IM} = commissure line (closed) against intermeatal line; FM_{IM} = facial midline against intermeatal line; H_{IM} = horizontal against intermeatal line; CS_{IM} = commissure line (smiling) against intermeatal line; IC_{IM} = intercuspid line against intermeatal line.

Discussion

In this study, a natural head posture was used. Cooke and Wei[24] found that natural head posture radiographic reproducibility was better using a mirror, and no statistically significant differences were detected between natural head posture recordings taken with or without ear posts. Solow and Tallgren[25] also reported better reproducibility on images of subjects using a mirror. Cooke and Wei[24] further reported better reproducibility with same-day repeat radiographs than with those taken 3 to 6 months later. In the present project, subjects were asked to stand on footprints in front of the digital camera and look straight forward without any head holder or head support. It took less than a minute to acquire the 3 images.

It was sometimes difficult to locate the center of the pupil on the image of the subject by inspection because the upper eyelid was superimposed on part of the pupil area, especially when the subject was smiling, and both of the eyelids tended to close. This project used the flash reflection from the pupil area, which was seen as a clear white area on the center of the pupil. This made it easier for the investigator to locate the center of the pupil even though the eyelids overlapped part of the pupil. However, there might still have been an error in this technique because the flash may not always be reflected from the center of the pupil. It was found on review that 91% (273 of 300) of all of the images in this project provided flash reflection from the center of the pupil, and the remaining images were within 2 pixels of center.

When casts have been mounted on an articulator by means of a facebow, the IM line is represented by the horizontal of the articulator as it rests on the laboratory bench. The angulation of other facial lines and of the horizon to the IM line is therefore of clinical importance, for it is the facial features and the horizon that influence the clinician's judgment in determining the correct alignment for the maxillary anterior teeth. The dental technician needs to be informed of the direction and magnitude by which this alignment varies from the IM line, ie, from the horizontal of the articulator. One method of communicating this information is by use of the Clinometer (Teledyne Water Pik), which records the chosen angle against the IM line.[26]

Although not statistically significant, the fact that the means of all facial lines and the horizontal were clockwise in relation to the IM line suggests that there may be a systematic, rather than random, asymmetry in the human head. Expressed in another way, it appears that the external auditory meatus on the left side tends to be at a higher level than on the right. There is some support in the experimental literature for this suggestion. Woo,[27] in a study of 800 ancient Egyptian skulls, found the right side to be on average significantly larger than the left. The difference was particularly marked in the vertical measurement of the parietal bone, which would have the effect of placing the external auditory meatus lower on the right. Ito et al,[28] in a study using the Clinometer on 200 subjects, found the mean angle of the IP line against the IM line to be 0.72 degree clockwise. If this trend is confirmed by future studies, it would have practical implications in prosthodontics. When working casts are mounted on an articulator by means of a facebow, the correct angulation for esthetic placement or restoration of the maxillary anterior teeth can be expected, on average, to be slightly clockwise to the axes of the articulator. If this angulation is ignored by the clinician and technician, and anterior restorations are set to the articulator horizontal axis, the restorations will appear acceptable on the articulator, but will sometimes show an unesthetic angulation when in the patient's mouth.

Conclusion

This study demonstrates how angular asymmetry of the face can be measured by using a digital camera and computer analysis. While individuals can show considerable variation, the mean angulation of the interpupillary line, the intercanthal line, both of the commissure lines, the occlusal plane, and the facial midline are not influenced by sex, age, or history of facial trauma and/or orthodontic treatment.

The angulation of the facial lines studied can vary from the true horizontal or vertical, or from each other, by up to several degrees in normal subjects. Although not confirmed statistically, there appears to be a systematic bias to these variations.

References

1. Güntürkün O. The Venus of Milo and the dawn of asymmetry research. Brain Cogn 1991;16:147–150.
2. Mulick JF. An investigation of craniofacial asymmetry using the serial twin-study method. Am J Orthod 1965;51:112–129.
3. Letzer GM, Kronman JH. A posteroanterior cephalometric evaluation of craniofacial asymmetry. Angle Orthod 1967;37:205–211.
4. Vig PS, Hewitt AB. Asymmetry of the human facial skeleton. Angle Orthod 1975;45:125–129.
5. Hewitt AB. A radiographic study of facial asymmetry. Br J Orthod 1975;2:37–40.
6. Shah SH, Joshi MR. An assessment of asymmetry in the normal craniofacial complex. Angle Orthod 1978;48:141–148.
7. Jain KK, Jain BK. Asymmetry in the skull. Acta Anat 1979;104: 349–352.
8. Tsuchiya M, Takasugi H, Kakiuchi K, Yoshida K, Sakuda M. Symmetry analysis of the human face based on Moire topography. J Osaka Univ Dent Sch 1988;28:17–25.
9. Melnick AK. A cephalometric study of mandibular asymmetry in a longitudinally followed sample of growing children. Am J Orthod 1992;101:355–366.
10. Araujo TM, Wilhelm RS, Almeida MA. Skeletal and dental arch asymmetries in individuals with normal dental occlusions. Int J Adult Orthod Orthognath Surg 1994;9:111–118.
11. Farkas LG, Cheung G. Facial asymmetry in healthy North American Caucasians. An anthropometrical study. Angle Orthod 1981;51:70–77.
12. Chebib FS, Chamma AM. Indices of craniofacial asymmetry. Angle Orthod 1981;51:214–226.
13. Thompson JR. Asymmetry of the face. J Am Dent Assoc 1943;30: 1859–1871.
14. Lundström A. Some asymmetries of the dental arches, jaws, and skull, and their etiological significance. Am J Orthod 1961;47: 81–106.
15. Björk A, Björk L. Artificial deformation and cranio-facial asymmetry in ancient Peruvians. J Dent Res 1964;43:353–362.
16. Brace RA, Hayward JR. Condylar hyperplasia and mandibular asymmetry: A review. J Oral Surg 1968;26:281–289.
17. Chaurasia BD, Goswami HK. Functional asymmetry in the face. Acta Anat 1975;91:154–160.
18. Cook JT. Asymmetry of the cranio-facial skeleton. Br J Orthod 1980;7:33–38.
19. Obwegeser HL, Makek MS. Hemimandibular hyperplasia—Hemimandibular elongation. J Maxillofac Surg 1986;14:183–208.
20. Cohen MM. Perspectives on craniofacial asymmetry. 1. The biology of asymmetry. Int J Oral Maxillofac Surg 1995;24:2–7.
21. Keles P, Diyarbakirli S, Tan M, Tan Ü. Facial asymmetry in right- and left-handed men and women. Int J Neurosci 1997;91:147–160.
22. Peck H, Peck S. A concept of facial esthetics. Angle Orthod 1970; 40:284–318.
23. Peck S, Peck L, Kataja M. Skeletal asymmetry in esthetically pleasing faces. Angle Orthod 1991;61:43–48.
24. Cooke MS, Wei SHY. The reproducibility of natural head posture: A methodological study. Am J Orthod 1988;93:280–288.
25. Solow B, Tallgren A. Natural head position in standing subjects. Acta Odontol Scand 1971;29:591–607.
26. Shannon JL, Rogers WA. Communicating patients' esthetic needs to the dental laboratory. J Prosthet Dent 1991;65:526–528.
27. Woo TL. On the asymmetry of the human skull. Biometrika 1931; 22:324–352.
28. Ito S, Tawada Y, Kurokawa H, Komatsu S, Kawata K, Mori Y, et al. Clinical effectiveness of Behrend facial clinometer [in Japanese with English abstract]. Shigaku 1991;79:335–339.