Journal of Dental Biomaterials
Shiraz University of Medical Sciences, Shiraz, Iran

Journal of Dental Biomaterials. 2014;**1**(2)

Software Designation to Assess the Proximity of Different Facial Anatomic Landmarks to Midlines of the Mouth and Face

Moshkelgosha V[a], Zare R[b], Safari A[c]

a. Orthodontics Research Center and Department of Orthodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran
b. Department of Oral and Maxillofacial Pathology, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran
c. Department of Prosthodontics, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran

ARTICLE INFO

Article History
Received: 26 June 2014
Accepted: 25 Sep 2014

Keywords:
Midline
Esthetic frame
Software

Corresponding Author:
Zare R
Department of Oral and Maxillofacial Pathology, School of Dentistry, Shiraz University of Medical Sciences, Shiraz, Iran
Tel: +98-9126909901
Email: mzare.zare85@gmail.com

Abstract

Statement of Problem: Recognition and determination of facial and dental midline is important in dentistry. Currently, there are no verifiable guidelines that direct the choice of specific anatomic landmarks to determine the midline of the face or mouth.
Objectives: The purpose of this study was to determine which of facial anatomic landmarks is closest to the midline of the face as well as that of the mouth.
Materials and Methods: Frontal full-face digital images of 92 subjects (men and women age range: 20-30 years) in smile were taken under standardized conditions; commonly used anatomic landmarks, nasion, tip of the nose, and tip of the philtrum were digitized on the images of subjects and aesthetic analyzer software used for midline analysis using Esthetic Frame. Deviations from the midlines of the face and mouth were measured for the 3 clinical landmarks; the existing dental midline was considered as the fourth landmark. The entire process of midline analysis was done by a single observer and repeated twice. Reliability analysis and 1-sample *t*- tests were conducted.
Results: The Intra-class correlation coefficients (ICCs) for reliability analysis of RFV and RCV measures made two times revealed that the reliabilities were all acceptable. The results indicated that each of the 4 landmarks deviated uniquely and significantly (P<.001) from the midlines of the face as well as mouth in both males and females.
Conclusions: There was a significant difference between the mean ratios of the chosen anatomic landmarks and the midlines of the face and mouth. The hierarchy of anatomic landmarks closest to the midline of the face is: (1) midline of the commissures, (2) nasion , (3) tip of philtrum,(4)dental midline, and (5) tip ofthe nose. The closest anatomic landmarks to the mouth midline are: (1) tip of philtrum, (2) dental midline, (3) tip of nose, and (4) nasion.

Cite this article as: Moshkelgosha V, Zare R, Safari A. Software Designation to Assess the Proximity of Different Facial Anatomic Landmarks to Midlines of the Mouth and Face. J Dent Biomater, 2014;1(2):50-56.

Introduction

Symmetry, which is defined as "correspondence in size, shape, and relative position of parts on opposite sides of a dividing line known as the midline", has been considered a key element to facial beauty [1, 2]. The symmetry plays a vital role for treatment planning in general dentistry and various specialties such as orthodontics, maxilofacial surgery and prosthodontics. A clear absolute definition of the "midline" is necessary for assessing the level of such symmetry in the face and dentition or achieving the best results through dento-

facial treatments. Traditionally, a diverse number of facial anatomic landmarks such as the bisector of the pupils, nasion, tip of the nose, tip of the philtrum, and chin are used to determine the facial and dental midlines [3, 4]. Some researchers advocate the use of intraoral landmarks, such as the incisive papilla, instead of the extra-oral landmarks for a more accurate determination of the maxillary dental midline [5, 6].

The recommendation of different methods and techniques for determination of the midline of the face or mouth in the literature, however, illustrates that there is no general agreement on how to determine such an important element. Most of the available literature limits the amount of tolerance of deviated dental midlines from the facial midline, a span of approximately 2 to 3 mm [4, 7, 8]. Farkas (1994), as an example, describes the facial midline in anthropometric interest, as a line defined by 3 anatomic points: nasion, subnasale, and the gnathion or menton[9]. This definition is neither objective nor repeatable, especially for research purposes.

In modern medicine, computers are used to create more accurate findings and diagnosis. Digital imaging has replaced conventional imaging and measuring tools. Therefore, digital software can be used to mark several landmarks on the face or in the mouth to specify an accurate and reliable facial midline for each person. Despite the advantages achieved in medical and dental technology, little has been done to create or test such valuable instrument.

The objectives of the study were to create a program for determining the facial midline using standardized digital images, to evaluate the proximity of facial anatomic landmarks to the midline of the face and to assess the hierarchy of the importance of facial anatomic landmarks for determining the midline of the oral commeasures. The facial anatomic landmarks analyzed were a combination of those traditionally used in clinical practice, such as nasion, tip of the nose (pronasale), tip of philtrum (labialesuperioris), and dental midline.

Materials and Methods

A standardized digital photographic method was set up. A facial aesthetic analyzer software was created. Its ability to determine a valid and reliable midline on digital photographs was tested. Furthermore, the relationship of the main facial anatomic landmarks with the determined midline and the repeatability of the obtained measurements were assessed through a pilot study.

Designing the Software and Picture Registration

Some of the commercial available programs (including Dolphin Imaging™, View Box™) were reviewed and the required capabilities of the software to be designed were determined according to the current study goals. The algorithms for each part of the software were written separately and connected together by data flow charting. The Visual Basic™ compiler and Access™ programs were used to create the flowchart database. After primary calibration and debugging, the install package was prepared for Microsoft Windows XP™ operating system.

The final program, the Aesthetic Analyzer software, was tested and provisionally approved by three orthodontists. To use this program; digital photographs should be taken in standardized way described below. A graphic interface software is used to assure the photographs` quality for measurement. The selected photographs are then guided through the point registration interface. An automatic point locator will mark the anatomical landmarks; however, the operator might need to identify and register the unrecognized ones or make fine corrections by the mouse pointer manually. In this situation, the operator can get help by using overall and localized zoom and vertical and horizontal lines. When the registration process is complete, the picture should be calibrated with a specially designed ruler in order to scale the measurements to real life-size. By pressing the "Tracing" button, the software draws the Esthetic frame according to the definitions provided. The required ratios (RFV and RCV) are calculated. The calculated measurements are presented in a table along with the graphic tracing of the Esthetic frame on the subject's face. The table and tracing can be printed.

Photographic Set-Up

Subjects are photographed using a standardized technique for frontal view of the face (Figure 1). A digital SLR camera (Canon Eos 400D, Japan) is used in this technique. A 70 mm focal lens (Sigma,Japan)

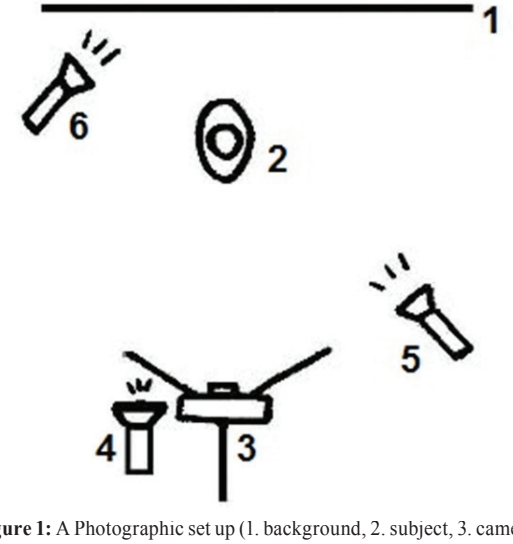

Figure 1: A Photographic set up (1. background, 2. subject, 3. camera with tripod, 4. primary flash, 5. secondary flash, 6. projector)

is used to achieve a natural size image with a 1:1 magnification ratio. A tripod is used to assure the appropriate height and horizontal positioning of the camera and to avoid vibration. A single flash is attached to the tripod by a lateral arm, at a distance of 27 cm from the optical axis of the camera and 75 degrees from the upper right angle to avoid the 'red-eye effect' on the photographs. The shutter speed is set at 1/125 per second and the opening of the diaphragm is put on f/11. This procedure is similar to the protocol described by Owens *et al* [13].

Each subject is told to stand against a white wall mount with their back of head, shoulders, hips and heels touching the wall. The head position is guided by a calibrated assistant assuming their natural head position, an approach which has been well documented in the literature [10-12]. The camera is positioned 1.5 meters from the subject's face with the visual axis being parallel to the floor of the room. A laser guide is used to adjust the height of the lens of the camera on the tripod so that it is at the eye level of the subject. Each subject should have 3 small marks placed by a single observer using a fine-tipped erasable marker, with a tip approximately 0.5 mm in diameter on the nasion, tip of the nose, and tip of the philtrum, to help locate the landmarks. The soft tissue landmark "nasion" should be positioned at the middle as possible in the frame so that the soft tissue "trigion " and "gonion" points are completely visible. Full-face standardized digital images are obtained with subjects in smile and eyes fully open. Images should be saved as TIFF format.

Landmarks and Measurements

Standard definitions for anatomic landmarks were used for all purposes of the study (Figure 2) .Lateral canthus was defined as the lateral angle formed by the meeting of the upper and lower eyelids [1], exocanthion, the point at the outer commissure of the eye fissure [9], nasion, the point in the midline of both the nasal root and nasofrontal suture [1, 9], philtrum, the vertical groove on the median line of the upper lip [1],commissure, a point or line of junction between two anatomic parts (the lips) [1, 14], cheilion and the point located at each labial commissure [9], and the tip of the nose (pronasale) was considered as the most protruded point of the apex of the nose [9]. These definitions were used for all clinical markings and to digitally construct an "Esthetic Frame".

The Esthetic Frame was adapted from Bidra *et al.* [15] and used to define the facial midline objectively. It was defined as an area on the human face, within which items of esthetic interest such as midlines, cants, and smile parameters are sensitively perceptible and objectively verifiable. Its superior border was defined by a line originating at the exocanthion of one eye and meeting the exocanthion of the other eye. The two lateral borders of the frame were then drawn as perpendicular lines from the exocanthion of each eye and were parallel to each other. The inferior border of

Figure 2: Aesthetic Analyzer software interface with landmarks digitized on the facial photograph

the frame was parallel to the superior line drawn at the most inferior border of the lower lip. This completed the four sides of the frame (Figure 3).

Furthermore, the facial midline was defined as the midline of the esthetic frame of the face. The dental midline was defined as the vertical line through the tip of the incisal embrasure between the 2 maxillary central incisors and parallel to the vertical lines of the esthetic frame of the face. The midline of the oral commissures was defined as a line bisecting the distance between the cheilions of the subject in smiling posture.

Relative facial midline value (RFV) was defined as the relative closeness of an anatomic landmark to the facial midline. The measured distance from the lateral border of the frame to the defined facial midline was considered a constant called "F." The measured distance from the lateral border of the frame to the nasion was considered a variable termed "n." The RFV was then obtained by dividing n by F. Similarly, RFVs were obtained for the other 3 anatomic landmarks: tip of the nose (t), tip of philtrum (p), and dental midline (d), by dividing them by the constant F. Numerical values for n/F, t/F, p/F, and d/F were thus obtained.

Relative commissural midline value (RCV) was defined as the relative closeness of an anatomic landmark to the midline of the oral commissures (center of the mouth). The measured distance from the midpoint of the intercommissural line to the right/left cheilion was considered a constant termed C. The measured distances (variables) were: from the nasion, nx, from the tip of the nose, tx, from the tip of philtrum, px, and from the dental midline, dx. The RCV was then obtained by dividing nx/C tx/C, px/C, and dx/C. The measureddistance from the lateral border of the Esthetic Frame to the midpoint of the commissures was described as a variable called Cx. Thus, the relationship between the midline of the commissures and that of the face was obtained by dividing Cx/F. The assignments for relativity of landmarks for both midlines were:

- RFV1 and RCV1: relativity of nasion to midline of the face and commissures;
- RFV2 and RCV2: relativity of tip of the nose to midline of the face and commissures;
- RFV3 and RCV3: relativity of tip of the philtrum to midline of the face and commissures;
- RFV4 and RCV4: relativity of dental midline to midline of the face and commissures;
- RFV5: relativity of the midline of the commissures with the midline of the face

Testing the Program

A randomly selected sample of 100 students of Shiraz Dental School who were between 20 and 30 years old were enrolled in the study. The study

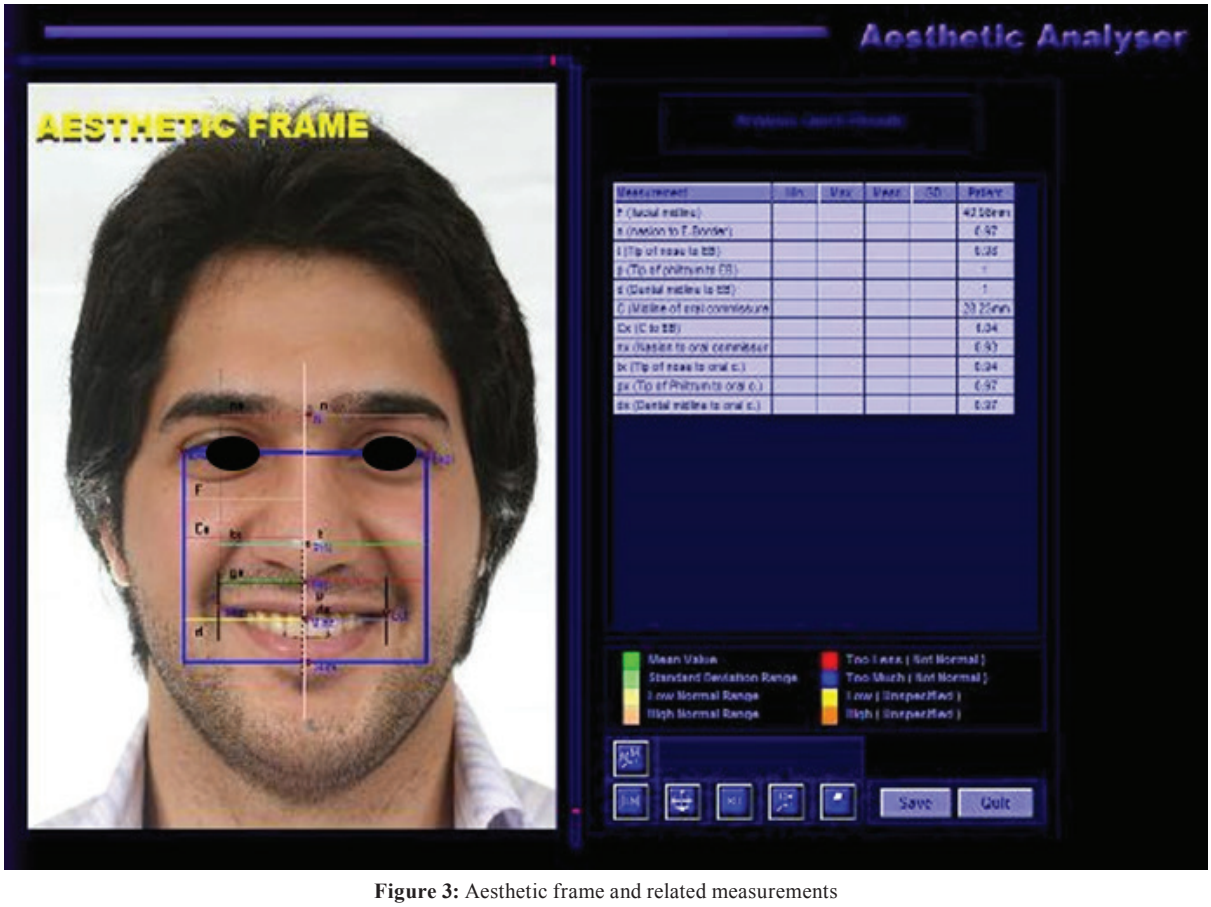

Figure 3: Aesthetic frame and related measurements

objectives and process were explained to them. Only those who agreed to be photographed and signed a consent form were included. Participants' age, sex, previous orthodontic treatment, and maxillo-mandibular relationship were recorded. The photographs were taken in the standardized method described above. Images with rotations of head around the vertical axis, obvious ophthalmic asymmetry, and those with inaccurate clinical marking were excluded. Subjects with craniofacial anomalies were also excluded from the study. The images were assessed randomly twice, one month apart, using the created Aesthetic Analyzer program by a calibrated examiner.

Statistical Analysis

The two sets of data were compared to assess the repeatability of measurements obtained by the created software. A reliability intra-class correlation coefficient (ICC) test was used for this purpose. The first set of data was used in other parts of the analysis. Two sets of independent t- tests were conducted for RFV and RCV values. The first set of t- tests was conducted to test the null hypothesis that the mean ratios of the RFV specified anatomic measures did not differ from 1.00 (whether they all lined up with the facial midline). A second set of independent t-tests was conducted to test the null hypothesis stating that the mean ratios of the RCV specified anatomic measures did not differ from 1.00 (whether they all lined up with the inter-commissural midline). The significance level was set at 0.05 level.

Results

The images of 92 participants were used in final analysis. The intra-class correlation coefficients (ICCs) for reliability analysis of RFVand RCV measures were between 0.73 to 0.99, indicating a high consistency between measurements made the first and second times (Table 1).

The analysis indicated that the difference between the mean ratio of each anatomic landmark and the midline of the face was statistically significant (P<.001) (Table2). The midline of the commissures was the closest, followed by nasion, tip of philtrum,the dental midline, and the tip of the nose. The results indicated that the difference between the mean ratio of each anatomic landmark and the midline of the commissures was statistically significant (P<.001) (Table 3). The tip of the philtrum was the closest, followed by the dental midline, tip of the nose, and nasion. These hierarchical relationships remained the same for both genders.

Table 1: Reliability analysis table

Parameter pair		ICC
RFV11 (Nasion)	RFV12	0.733
RFV21 (Tip of nose)	RFV22	0.896
RFV31 (Tip of philtrum)	RFV32	0.959
RFV41 (Dental midline)	RFV42	0.979
RFV51 (Midline of commissures)	RFV52	0.995
RCV11 (Nasion)	RCV12	0.968
RCV21 (Tip of nose)	RCV22	0.913
RCV31 (Tip of philtrum)	RCV32	0.950
RCV41 (Dental midline)	RCV42	0.975

RFV: Relative facial midline value, RCV: Relative commissural midline value

Table 2: One-sample t -test for hierarchy of landmarks for midline of the face

Measurement	Mean	SD	P value
Midline of commissures (RFV5)			
Male	0.9781	0.730	<0.001
Female	0.9782	0.754	
Dental midline(RFV4)			
Male	0.9596	0.029	<0.001
Female	0.9582	0.033	
Tip of philtrum (RFV3)			
Male	0.9602	0.028	<0.001
Female	0.9622	0.027	
Nasion (RFV1)			
Male	0.9758	0.017	<0.001
Female	0.978	0.020	
Tip of nose (RFV2)			
Male	0.9569	0.035	<0.001
Female	0.9552	0.036	

RFV: Relative facial midline value

Table 3: One-sample t -test for hierarchy of landmarks for commissural midline

Measurement	Mean	SD	P value
Dental midline (RCV4)			
Male	0.9633	0.033	<0.001
Female	0.9642	0.026	
Tip of philtrum (RCV3)			
Male	0.9640	0.034	<0.001
Female	0.9663	0.025	
Nasion (RCV1)			
Male	0.939	0.053	<0.001
Female	0.935	0.049	
Tip of nose (RCV2)			
Male	0.945	0.048	<0.001
Female	0.938	0.050	

RCV: Relative commissural midline value

Discussion

A software to determine the facial midline and to assess the symmetry of facial anatomical landmarks using digital photographs was prepared and tested in this study. The results showed that the created software, the Aesthetic Analyzer, was highly valid and reliable for the purpose it was created for. The results showed that a significant difference existed between the distances of chosen facial anatomic landmarks with the facial and commissural midlines.

In the present study, the natural head position was guided to the true horizon by a single investigator, and care was taken to ensure that the subjects did not rotate their heads along the vertical axis to reduce the unwanted errors in the study. To reduce the error in the landmark point's digitization, the markings for each anatomic landmark were made clinically prior to locate them on the digital image. The use of computer in drawing the lines and framing the picture could possibly help reduce inherent human errors in measurements which were presented in prior studies [15]. But not all human errors could be eliminated especially in marking landmarks clinically. Of the various clinical landmarks, marking the soft tissue nasion and the tip of the nose was much difficult due to the inherent anatomy of the nose [9]. This is possibly the cause of difference in the result of the current study and that of previous one [15].

The midline of the oral commissures was considered as a determined anatomic landmark while analyzing the hierarchical order for facial midlines. It ranked the closest to the facial midline, in comparison to all of the landmarks analyzed. Similar findings are reported in Bidra`s [15] study. This may be the result of using the concept of esthetic frame in both studies.

The philtrum or tip of the vermillion border has been assumed by several studies in the past to represent the facial midline [16-18]. The present study showed that the tip of the philtrum ranked the third in the hierarchy of facial midlines, superseded only by the midline of the commissures and nasion. This reinforces the credibility of the tip of the philtrum as a reliable landmark in the determination of the midlines of the face and mouth.

The dental midline in our study was ranked the second for midline of the commissures. We don't consider the axial angulations of the dental midline in its analysis, however. It can be inferred that the incisive papilla, usually found between the two maxillary central incisors, may be an acceptable landmark for determination of the mouth midline in edentulous patients, as reported in the past [15]. Dental midline, however, is not good in facial midline determination. The same findings are reported in Bidra *et al.*`s study.

The nasion has been considered to be a good location along the middle fifth of the face, but its relation to the facial and commissural midline has not been studied previously. Based on the current study, soft tissue nasion is an adequate clinical landmark to determine the midline of the face, since it is closest to the facial midline after midline of commissures. But its practicality in determining the midline of mouth is questionable. Furthermore, its distant location from the dental midline may not result in easy determination and analysis.

The tip of the nose was the most deviated landmark with regard to the facial midline. However, it ranked higher than the nasion with regard to the midline of the commissures. This landmark is not advised, therefore, in locating either midline.

The use of ratios instead of linear measurement as tools to examine the relationship of the anatomic landmarks and develop the hierarchy is an advantage of the current study. It is more important for a clinician to know the hierarchy or the best choice of anatomic landmarks that could be used in determination of the midline for a particular patient, rather than to find out the mean linear deviations of anatomic landmarks of a certain population. The applied methods in this study would have permitted sufficient accuracy to analyze linear deviations, but ratios are preferred because they can more easily be compared to the results of similar studies in different populations.

The current study was done on the population chosen based on convenience sampling, with the

sample distribution being approximately normal. This study provides baseline information about the hierarchical relationships of various facial anatomic landmarks to the midlines of the face and mouth. Further population-based studies are needed to ensure the practical use of the created software.

Conclusions

A relatively practical and reliable software was created to determine the facial and commissural midlines and assess the position of anatomical landmarks from these lines. There was a significant difference between the mean ratios of the chosen anatomic landmarks and the midlines of the face and mouth. The hierarchy of anatomic landmarks closest to the midline of the face was: (1) midline of the commissures, (2) nasion , (3) tip of philtrum, (4)dental midline and (5) tip ofthe nose. The closest anatomic landmarks to the mouth midline were: (1) tip of philtrum, (2) dental midline, (3) tip of nose, and (4) nasion.

Acknowledgements

This manuscript is based on Dr.Razieh Zare DDS thesis (No.1381) from School of Dentistry of Shiraz University of Medical Sciences.

Conflict of Interest: None declared.

References

1. Merriam-Webster's medical dictionary. Springfield: Merriam-Webster; 2006. Available at: http://www.nlm.nih.gov/medlineplus/mplusdictionary.html.
2. Rhodes G. The evolutionary psychology of facial beauty. Annu Rev Psychol. 2006;57:199-226.
3. Arnett GW, Bergman RT. Facial keys to orthodontic diagnosis and treatment planning--Part II. Am J Orthod Dentofacial Orthop. 1993;103:299-312.
4. Beyer JW, Lindauer SJ. Evaluation of dental midline position. Semin Orthod. 1998;4:146-152.
5. Zarb GA, Carlsson GE, Bolender CL, editors. Boucher's prosthodontic treatment for edentulous patients. 11th Edition. St. Louis: Mosby;1997. 309-310.
6. Latta GH Jr. The midline and its relation to the anatomic landmarks in the edentulous patient. J Prosthet Dent. 1988;59:681-683.
7. Johnston CD, Burden DJ, Stevenson MR. The influence of dental to facial midline discrepancies on dental attractiveness ratings. Eur J Orthod. 1999;21:517-522.
8. Rosenstiel SF, Rashid RG. Public preferences for anterior tooth variations: a web-based study. J Esthet Restor Dent. 2002;14:97-106.
9. Farkas LG. Anthropometry of the head and face in medicine. 2nd Edition. New York: Raven Press Limited; 1994.20-25.
10. Peng L, Cooke MS. Fifteen-year reproducibility of natural head posture: A longitudinal study. Am J Orthod Dentofacial Orthop. 1999;116:82-85.
11. Cooke MS. Five-year reproducibility of natural head posture: a longitudinal study. Am J Orthod Dentofacial Orthop. 1990;97:489-494.
12. Cooke MS, Wei SH. The reproducibility of natural head posture: a methodological study. Am J Orthod Dentofacial Orthop. 1988;93:280-288.
13. Owens EG, Goodacre CJ, Loh PL, , *et al*. A multicenter interracial study of facial appearance. Part 1: A comparison of extraoral parameters. Int J Prosthodont. 2002;15:273-282.
14. The glossary of prosthodontic terms. J Prosthet Dent. 2005;94:10-92.
15. Bidra AS, Uribe F, Taylor TD, *et al*. The relationship of facial anatomic landmarks with midlines of the face and mouth.J Prosthet Dent. 2009;102:94-103.
16. Cardash HS, Ormanier Z, Laufer BZ. Observable deviation of the facial and anterior tooth midlines. J Prosthet Dent. 2003;89:282-285.
17. Miller EL, Bodden WR Jr, Jamison HC. A study of the relationship of the dental midline to the facial median line. J Prosthet Dent. 1979;41:657-660.
18. Arnett GW, McLaughlin RP. Facial and dental planning for orthodontists and oral surgeons. St. Louis: Elsevier; 2004. 52-70.