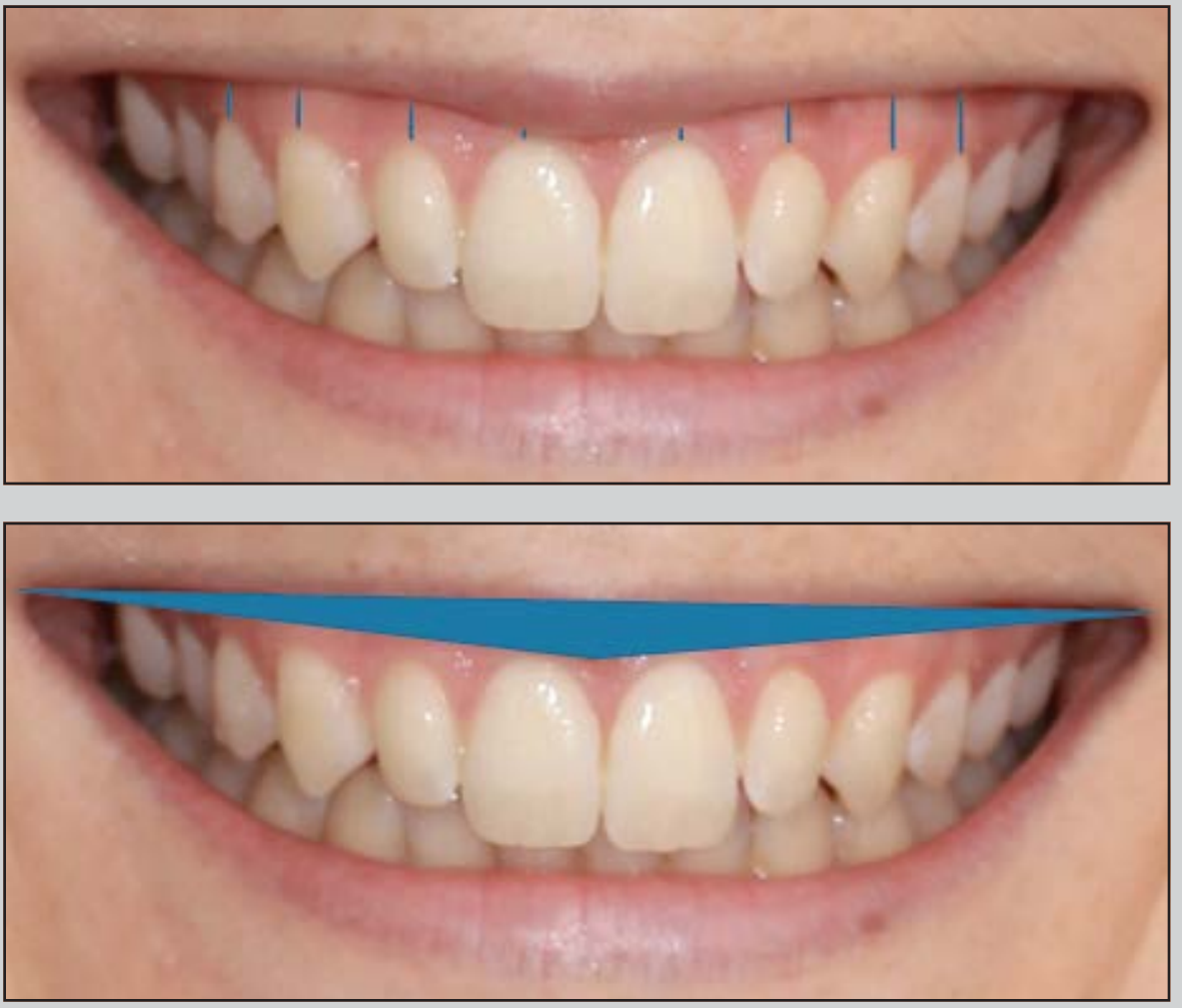

# Analysis of Select Facial and Dental Esthetic Parameters

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*This clinical study examined objective smile parameters in the natural anterior dentition. Standardized intraoral and extraoral photographs were taken of 106 Caucasian adults (54 women, 52 men) with a healthy dentition. The following parameters were analyzed: correlation of dental and facial midline, upper lip position and curvature, relationship of the maxillary anterior incisal curve with lower lip, number of teeth displayed in a smile, distance between maxillary anterior teeth and lower lip, slope of tooth, and lip arc. The simple frequency distribution of measured variables revealed an average smile with coinciding dental and facial midlines, an average smile line, and a straight upper lip curvature. With an average smile, the maxillary anterior teeth did not touch the lower lip, teeth were displayed up to the second premolar, and the maxillary anterior incisal curve was parallel to the lower lip. Oval was the most prevalent tooth form. A slope of 9 degrees was detected for the mean tooth arc and 13 degrees for the mean lip arc. The outcomes of this clinical study provide a quantifiable frame for esthetic evaluation, treatment planning, and restoration fabrication.* (Int J Periodontics Restorative Dent 2014;34:623–629. doi: 10.11607/prd.1969)

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Dentistry has experienced a fundamental change from a strictly restorative to a more cosmetic and esthetic emphasis.[1] Patients' self-esteem and quality of life seem to be greatly influenced by successful and satisfactory restoration of their teeth.[2] It is, therefore, the aim of modern dentistry to restore not only functional efficacy but also esthetics of teeth.[3] Attempts to create an individualized dental composition for each patient interfere with standardized concepts of beauty, set by social and cultural standards.[4] The facial midline is often the starting point of a dental esthetic evaluation.[1] Miller et al[5] investigated the clinical relationship of dental and facial midlines. While the negative influence of a midline deviation on the attractiveness of a smile was often discussed,[6] the mean threshold for acceptable dental midline deviation was determined to be 4 mm.[7] Furthermore, a vertical deviation seems to be less acceptable than a horizontal one.[7] Dong et al[8] reported that in the majority of smiles the maxillary anterior teeth do not contact the lower lip. Tjan et al[9] reported that an average smile displays the six maxillary anterior

teeth as well as the first and second premolar. Several studies calculated the average tooth display to include all maxillary teeth up to the second premolar.[1,8,10] Frush and Fisher[11] were first to investigate harmony between the curve of the anterior teeth and the lower lip. The ideal incisal line of the maxillary dentition was discovered to be parallel to the curve of the lower lip for both men and women.[12] It seemed, however, that a straight line is more acceptable in men than in women.[13] Tjan et al[9] found that an average smile exhibits the full length of the maxillary anterior teeth. Studies by Peck et al[14] revealed that a high smile line is found more often in women, and a low smile line is found more often in men. Many attempts were made to define a universal concept for anterior tooth shape selection. Williams[15] concluded that human teeth could be classified into three principal shapes: rectangular, triangular, and ovoid. He suggested that tooth shape should be determined by the facial outline. However, this theory was negated by recent studies.[14,16] Other authors suggested tooth shapes should be based on stereotypes: Women should have round, soft, delicate teeth (ovoid), and men should have square, angular teeth. However, other studies rejected this theory,[17,18] and there is no scientifically validated protocol on how to select a patient's tooth shape. Some investigators attempted to geometrically determine the tooth arc. Parekh et al[19] reported that smiles with ideal and excessive smile arcs were more acceptable than those with a flat smile arc. Dong et al[8] analyzed the tooth arc with geometric parables and reported that the slope of the tooth arcs was higher than the slope of the lip arcs.

The aim of this study was to assess fundamental esthetic parameters in natural smiles and dentitions to establish guidelines that assist dentists in esthetic analysis, treatment planning, and restoration fabrication.

## Method and materials

This study was conducted after approval by the institutional review board of Freiburg University. Written informed consent was obtained from all participants. The study population consisted of 106 adults (54 women and 52 men) between 19 and 29 years of age (mean: 24.5 years) who met the inclusion criteria.

Inclusion criteria were body mass index (BMI) between 18.5 and 25 kg/m$^2$, age between 18 and 30 years, and Caucasian race. Exclusion criteria included restorations; aplasia and/or hypoplasia; caries; gingival recession or hyperplasia > 1 mm; erosion, attrition, abrasion, or abfraction > 1 mm in the area between the maxillary first premolars; current orthodontic treatment; and crowding hindering an analysis.

Dental and facial parameters were analyzed with standardized intra- and extraoral photographs. The following photographs were obtained: right and left profile, frontal full face, spontaneous smile (Fig 1), posed smile, and maxillary anterior region. All photographs were taken with a digital single lens reflex camera (Canon EOS 50D, Canon USA) with standardized settings. Distance, height, and orientation of the camera toward the participants were standardized, and all photographs were taken in one room by one investigator. All photographs were analyzed and evaluated by one examiner after a training and calibration phase. The examiner realigned the photographs to the papillary line with an image editing program (Adobe Photoshop 7.0, Adobe Systems), aided by a raster graphic. The facial midline was determined with a raster graphic angled to the pupillary line. Two anatomical landmarks were defined: the bisection of the pupillary line and the philtrum. This facial midline was compared to the dental midline, defined as a line through the contact point between the two maxillary central incisors that is perpendicular to the pupillary line (Fig 2).

The upper lip position was divided into three categories,[9] depending on the percentage of visible teeth and gingiva (Fig 3): high smile line revealing 100% of the maxillary anterior teeth and a contiguous band of gingiva, average smile revealing 75% to 100% of the maxillary anterior teeth and interproximal papilla, and a low smile line revealing less than 75% of the maxillary anterior teeth.

Three points were drawn to analyze the upper lip curvature: one on each corner of the mouth and one in the middle on the lowest point of the upper lip. These points were connected to form a triangle (Fig 4). Three categories were classified: "upward" (the two points in the corners higher than the center), "straight"

**Fig 1** (left) *Example of a spontaneous smile image.*

**Fig 2** (right) *Analysis of the dental versus facial midline.*

**Fig 3** *Analysis of the upper lip position.*

**Fig 4** *Analysis of the upper lip curvature.*

**Fig 5** *Analysis of the relationship between the maxillary anterior teeth and lower lip.*

**Fig 6** *Analysis of the number of teeth displayed in a smile.*

(all three points on a straight line), and "downward" (the two points in the corners lower than the center).

The relationship between the maxillary anterior teeth and the lower lip was categorized as "slightly covering," "touching," or "not touching" by measuring the geometric distance between the incisal edge and the upper border of the lower lip (Fig 5).

The number of teeth displayed during a smile was analyzed by counting visible teeth (Fig 6). A tooth was counted as visible when more than 50% of its surface was revealed. Smiles were categorized as displaying teeth up to the first premolar, the second premolar, the first molar, or the second molar.

The relationship of the maxillary anterior incisal curve with the lower lip was determined by drawing a line along the incisal edges of the maxillary central incisors to the cusp tips of the maxillary canines (Fig 7). Three categories were defined in reference to the upper border of the lower lip: "parallel" (the two lines parallel to each other), "straight" (maxillary teeth connected by a straight line), or "reverse" (maxillary teeth forming a reverse line).

**Fig 7** *Analysis of the correlation between maxillary anterior incisal curve and lower lip.*

**Fig 9** *Analysis of the slopes of the maxillary tooth arc and the lower lip arc.*

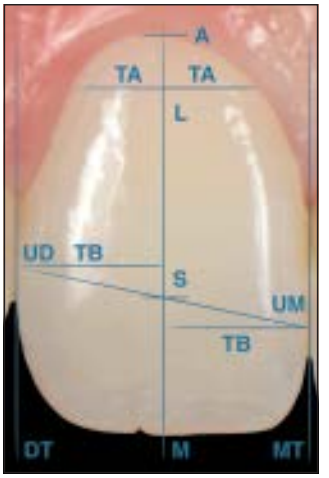


**Fig 8** Analysis of tooth shape. TA = apical widest stretch across the tooth; TB = basal widest stretch across the tooth; DT = distal tangent; MT = mesial tangent; M = tooth midline; A = most apical point of intersection between the median and the outline; UD = most apical point of intersection. between the outline and the tangent; UM = most incisal point of intersection between the outline and the tangent; S = intersection of the midline and line UDUM; L = 4/5 sectors of line AS.

Categories for the tooth shape were "triangular," "oval," or "quadrangular" and were determined for the right central incisor. Graphing software (Origin 8.5, OriginLab) was used. The classifications and analytic procedure were adopted from Wolfart et al[2]: Measurements were taken by dividing the tooth width in the cervical/apical region by the greatest width of the tooth, tracing two tangents to the mesial and distal contours. The largest tooth width was determined by inserting two horizontal lines, one on the lower intersection of the mesial tangent with the tooth contour and one on the upper intersection of the distal tangent, constructing the equidistant to the two previous lines (S). Afterward, the tooth midline was constructed and divided into five parts, followed by a horizontal line traced on top of the upper fifth part of the division. Finally, the absolute value of line TA (apical widest stretch across the tooth) was divided by the absolute value of line TB (basal widest stretch across the tooth; Fig 8). Based on this reference value, quotient dental forms were classified as "triangular" ($\leq 0.61$), "oval" ($> 0.61$ and $< 0.7$) or "quadrangular" ($\geq 0.70$).

The slope of a straight line drawn from the incisal edges of the maxillary incisors and the cusp tips of the maxillary canines was analyzed and compared to the slope of a straight line through the corresponding points of the lower lip (Fig 9). Photographs were viewed in the graphing software and inserted in a graphic coordinate system. The gradient of the line segments were assessed with a gradient triangle.

All calculations were performed with the statistical software SAS 9.1.2 (SAS Institute). Simple tables were used to show frequencies (and percentages) of the measured variables. To quantify associations between sex and variables, the chi-square test (or Fisher exact test) was used. Resulting $P$ values $< .05$ showed a significant association.

## Results

All parameters were investigated by sex and as an aggregate. Eighty-five percent of participants had dental midlines that coincided with the facial midline. Only 15% showed a midline shift (Table 1). No sex-dependent differences were obtained for this parameter ($P = .79$). The majority of participants (52%)

showed an average smile line, while 38% had a high smile line, and only 10% a low smile line (Table 2). A statistically significant sex dimorphism was obtained ($P < .05$), indicating that a high smile line appeared to be a more female feature and an average smile line a more male feature. Of all participants, 33% had an upward smile, 34% a straight smile, and 33% a downward smile (Table 3). No sex-dependent differences were obtained for this measured parameter ($P = .56$). A non-touching relationship between the maxillary anterior teeth and the lower lip was most common (75%). Relatively few participants had touching smiles (23%), and only 3% had a slightly covering smile (Table 4). No sex-dependent differences were found ($P = .86$). Twenty-four percent of participants displayed teeth up to the first premolar, 45% up to the second premolar, 31% up to the first molar, and none to the second molar (Table 5). No sex-dependent differences were found ($P = .75$). Most participants (63%) had an anterior incisal curve that was parallel to the lower lip; 27% had a straight line, and only 9% had a reverse curve (Table 6). A statistically significant sex-related dimorphism was apparent ($P = .01$): A straight incisal line was more prevalent in women than in men, and a reverse curve was more frequent in men than in women. The right central incisor was "triangular" in 10%, "oval" in 63%, and "quadrangular" in 26% of the study population (Table 7). No sex-dependent differences were obtained ($P = .54$). The mean tooth arc revealed a slope of 9 degrees and the mean lip arc a slope of 13 degrees. There was a statistically significant difference between the slope of the tooth arc and the slope of the lip arc ($P = .003$). With the results segregated by sex, a statistically significant difference was obtained in the slope of the tooth arc (right side) and the lip arc (left side), indicating that men had a flatter slope of the tooth arc ($P = .03$) and a steeper slope of the lip arc ($P = .03$). A statistically significant difference was obtained between the right and left sides of the slope of the tooth arc ($P < .01$).

**Table 1 Results of midline assessment**

| Participants | Coinciding (%) | Not coinciding (%) |
|---|---|---|
| Total | 85 | 15 |
| Women | 83 | 17 |
| Men | 87 | 13 |

**Table 2 Results of lip position assessment**

| Participants | High (%) | Average (%) | Low (%) |
|---|---|---|---|
| Total | 38 | 52 | 10 |
| Women | 48 | 41 | 11 |
| Men | 27 | 63 | 10 |

**Table 3 Results of the upper lip curvature assessment**

| Participants | Upward (%) | Straight (%) | Downward (%) |
|---|---|---|---|
| Total | 33 | 34 | 33 |
| Women | 33 | 39 | 28 |
| Men | 33 | 29 | 38 |

**Table 4 Results of the assessment of the relationship between maxillary anterior teeth and the lower lip**

| Participants | Slightly covering (%) | Touching (%) | Not touching (%) |
|---|---|---|---|
| Total | 3 | 22 | 75 |
| Women | 2 | 24 | 74 |
| Men | 4 | 21 | 75 |

**Table 5 Results of the assessment of teeth displayed in a smile**

| Participants | First premolar (%) | Second premolar (%) | First molar (%) | Second molar (%) |
|---|---|---|---|---|
| Total | 24 | 45 | 31 | 0 |
| Women | 21 | 46 | 33 | 0 |
| Men | 27 | 44 | 29 | 0 |

**Table 6** Results of the assessment of parallelism of the maxillary anterior incisal curve with the lower lip

| Participants | Parallel (%) | Straight (%) | Reverse (%) |
|---|---|---|---|
| Total | 64 | 27 | 9 |
| Women | 65 | 33 | 2 |
| Men | 62 | 21 | 17 |

**Table 7** Results of the tooth shape assessment

| Participants | Triangular (%) | Oval (%) | Quadrangular (%) |
|---|---|---|---|
| Total | 10 | 63 | 27 |
| Women | 7 | 63 | 30 |
| Men | 14 | 63 | 23 |

## Discussion

Several inclusion and exclusion criteria for participation in this study were determined to obtain a more heterogenous patient pool. Since previous studies found ethnic- and age-dependent differences, the authors applied age, race, and BMI as inclusion criteria.[20–23]

Digital photography is a cost- and time-effective method that was predominantly used in similar studies, which allows comparisons with those studies.[24–31] In order to minimize subjective variance and to obtain comparative data, classifications and evaluation parameters were adopted from the current literature.[1,24] The present analysis revealed that 85% of participants had a dental midline that coincided with the facial midline. This is in accordance with earlier studies on this subject.[1,5] Therefore, it can be assumed that a coinciding midline assessment is most prevalent in nature and should be realized in prosthetic dental treatment for an esthetic outcome.

Regarding the upper lip position, a high smile line appeared to be a more female feature, while an average smile line was a predominantly male feature. This result validates earlier investigations.[1,8–10,14] As a consequence, both male and female patients reveal 75% to 100% of the maxillary anterior teeth and a contiguous band of gingiva. It is, therefore, an important factor during treatment planning of anterior restorations and the associated gingival architecture.

The balanced distribution of the categories of the upper lip curvature indicated a natural variety in the position of the upper lip. A non-touching relationship between the maxillary anterior teeth and the lower lip was most common and is viewed as the most esthetic relationship.

The current results showed that nearly half of the participants displayed teeth up to the second premolar during a smile. This finding indicates that the visible area involves more than just the anterior teeth, which verifies the findings of recent studies.[1,8–10,28] This is an important factor when treatment planning anterior restorations, especially in terms of a "smile makeover": The width of the smile and number of exposed teeth have to be considered. Esthetic restoration of visible posterior teeth may be necessary to achieve a harmonious outcome.

The high incidence of parallel and straight incisal curvatures and the sex differences were statistically significant. An incisal curve parallel to the lower lip is the most attractive, as reported by Fradeani.[12]

Many attempts have been made to unify and quantify the selection of anterior tooth shapes. An oval central incisor tooth shape was most common in patients evaluated in this study. When in doubt during denture tooth selection, choosing central incisors with an oval shape may, therefore, have a greater chance to correlate with the any previously existing natural teeth than other shapes, regardless of the patient's sex. The prevalence of an ovoid tooth form has been documented in several other studies.[2,32]

The slopes of the tooth and lip arcs are rarely discussed in the literature,[8] and further investigations on this subject seem necessary. A slope of 9 or 12 degrees is a small dimension and difficult to directly apply to the design and fabrication of crowns or prostheses.

The obtained results show clinical significance and are, therefore, important for esthetic rehabilitations. The obvious variations within those parameters delineate an esthetically acceptable range, which serves as a quantifiable frame for individual

and patient-centered assessment, treatment planning, and restoration fabrication. While this clinical study determined several of these parameters, additional research is necessary to verify these findings in other patient populations and with advanced methods.

## Conclusions

The outcomes of this clinical study provide a quantifiable frame for esthetic evaluation, treatment planning, and restoration fabrication. A dental midline that coincides with the facial midline, an average smile line, and a straight upper lip curvature are most prevalent. During a smile, the maxillary anterior teeth should not touch but should follow the curvature of the lower lip. The second premolars should be considered part of the esthetic zone, and oval is the most common tooth shape.

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## References

1. Al-Johany SS, Alqahtani AS, Alqahtani FY, Alzahrani AH. Evaluation of different esthetic smile criteria. Int J Prosthodont 2011;24:64–70.
2. Wolfart S, Menzel H, Kern M. Inability to relate tooth forms to face shape and gender. Eur J Oral Sci 2004;112:471–476.
3. Brunzel S, Kern M, Freitag S, Wolfart S. Aesthetic effect of minor changes in incisor angulation: An internet evaluation. J Oral Rehabil 2006;33:430–435.
4. Brisman AS. Esthetics: A comparison of dentists' and patients' concepts. J Am Dent Assoc 1980;100:345–352.
5. 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.
6. Ker AJ, Chan R, Fields HW, Beck M, Rosenstiel S. Esthetics and smile characteristics from the layperson's perspective: A computer-based survey study. J Am Dent Assoc 2008;139:1318–1327.
7. Kokich VO Jr, Kiyak HA, Shapiro PA. Comparing the perception of dentists and lay people to altered dental esthetics. J Esthet Dent 1999;11:311–324.
8. Dong JK, Jin TH, Cho HW, Oh SC. The esthetics of the smile: A review of some recent studies. Int J Prosthodont 1999;12: 9–19.
9. Tjan AH, Miller GD, The JG. Some esthetic factors in a smile. J Prosthet Dent 1984; 51:24–28.
10. Maulik C, Nanda R. Dynamic smile analysis in young adults. Am J Orthod Dentofacial Orthop 2007;132:307–315.
11. Frush J, Fisher R. The dynesthetic interpretation of dentogenic concept. J Prosthet Dent 1958;8:558–581.
12. Fradeani M. Esthetic Analysis: A Systematic Approach to Prosthetic Treatment. Chicago: Quintessence, 2004.
13. Witt M, Flores-Mir C. Laypeople's preferences regarding frontal dentofacial esthetics: Periodontal factors. J Am Dent Assoc 2011;142:925–937.
14. Peck S, Peck L, Kataja M. Some vertical lineaments of lip position. Am J Orthod Dentofacial Orthop 1992;101:519–524.
15. Williams JL. A New Classification of Human Tooth Forms with Special Reference to a New System of Artificial Teeth. New York: Dentists' Supply, 1914.
16. Gomes VL, Goncalves LC, do Prado CJ, Junior IL, de Lima Lucas B. Correlation between facial measurements and the mesiodistal width of the maxillary anterior teeth. J Esthet Restor Dent 2006; 18:196–205.
17. Sherfudhin H, Abdullah MA, Khan N. A cross-sectional study of canine dimorphism in establishing sex identity: Comparison of two statistical methods. J Oral Rehabil 1996;23:627–631.
18. Singh SP, Goyal A. Mesiodistal crown dimensions of the permanent dentition in North Indian children. J Indian Soc Pedod Prev Dent 2006;24:192–196.
19. Parekh SM, Fields HW, Beck M, Rosenstiel S. Attractiveness of variations in the smile arc and buccal corridor space as judged by orthodontists and laymen. Angle Orthod 2006;76:557–563.
20. Bell RA. The geometric theory of selection of artificial teeth: Is it valid? J Am Dent Assoc 1978;97:637–640.
21. Dummet CO, Barens G. Pigmentation of the oral tissues: A review of literature. J Periodontol 1967;38:369–378.
22. Lew KK, Ho KK, Keng SB, Ho KH. Soft-tissue cephalometric norms in Chinese adults with esthetic facial profiles. J Oral Maxillofac Surg 1992;50:1184–1190.
23. Owens EG, Goodacre CJ, Loh PL, et al. A multicenter interracial study of facial appearance. Part 2: A comparison of intraoral parameters. Int J Prosthodont 2002; 15:283–288.
24. Dong JK, Rashid RG, Rosenstiel SF. Smile arcs of Caucasian and Korean youth. Int J Prosthodont 2009;22:290–292.
25. Bidra AS, Uribe F, Taylor TD, Agar JR, Rungruanganunt P, Neace WP. The relationship of facial anatomic landmarks with midlines of the face and mouth. J Prosthet Dent 2009;102:94–103.
26. Hunt O, Johnston C, Hepper P, Burden D, Stevenson M. The influence of maxillary gingival exposure on dental attractiveness ratings. Eur J Orthod 2002;24: 199–204.
27. 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.
28. Kapagiannidis D, Kontonasaki E, Bikos P, Koidis P. Teeth and gingival display in the premolar area during smiling in relation to gender and age. J Oral Rehabil 2005;32:830–837.
29. Krishnan V, Daniel ST, Lazar D, Asok A. Characterization of posed smile by using visual analog scale, smile arc, buccal corridor measures, and modified smile index. Am J Orthod Dentofacial Orthop 2008; 133:515–523.
30. Pedrosa VO, Franca FM, Florio FM, Basting RT. Study of the morpho-dimensional relationship between the maxillary central incisors and the face. Braz Oral Res 2011; 25:210–216.
31. Van der Geld P, Oosterveld P, Kuijpers-Jagtman AM. Age-related changes of the dental aesthetic zone at rest and during spontaneous smiling and speech. Eur J Orthod 2008;30:366–373.
32. Brunetto J, Becker MM, Volpato CA. Gender differences in the form of maxillary central incisors analyzed using AutoCAD software. J Prosthet Dent 2011;106: 95–101.