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Angles of facial convexity in different skeletal Classes

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SUMMARY The objective of this study was to investigate whether it is possible to use a lateral (profile) photograph to determine the underlying skeletal Class and which reference points of the angle of convexity are most suitable for this purpose. Profile photographs and lateral cephalographs included in the baseline data for 180 orthodontic patients were retrospectively evaluated. The subjects were assigned to skeletal Classes based on Wits values obtained by radiolographic analysis. The Class I subjects were 58 patients (22 males, 36 females) with an average age of 13.63 ± 2.1 years, the Class II subjects 60 patients (37 males, 23 females) with an average age of 13.60 ± 2.6 years, and the Class III subjects 62 patients (28 males, 34 females) with an average age of 11.65 ± 3.3 years. The angles measured were A′OrB′ (=POrA′–POrA′), A′N′B′, and the angle of convexity with its variants (N′SnPog′, N′A′Pog′, TrSnPog′, TrA′Pog′, Gl′SnPog′, and Gl′A′Pog′). These angles were statistically evaluated using a two-sided *t*-test and linear discriminant analysis.

Class II and Class III subjects exhibited highly significant differences ($P < 0.001$) for all angles. Class I and Class III exhibited highly significant differences ($P < 0.001$) for almost all angles, and significant differences for A′N′B′ ($P < 0.05$). Class I and Class II differed significantly ($P < 0.05$) only for some angles (N′SnPog′, TrA′Pog′, Gl′SnPog′, and Gl′A′Pog′). The error within the linear discriminant analysis was smallest for N′SnPog′, GlA′Pog′, and TrA′Pog′ angles. However, the method error according to Dahlberg yielded rather high values for all angles (1.07–1.17 degrees).

Discrimination between skeletal Class I and Class III was easier than that between Class I and Class II. One of the reasons may be that the subclasses division I and division II were not distinguished within the Class II subjects.

Introduction

Soft tissue profiles were analysed long before lateral cephalographs became established. Toward the end of the 18th century, Camper (1794) introduced a line and angle subsequently named after him in anthropology in order to demonstrate race-related differences and evolutionary developments. In the early 19th century, Retzius classified the human races as either orthognathic or prognathic (Neger, 1959), while Case (1921) described specific regions of the human face that changed most profoundly after orthodontic treatment. When the lateral cephalograph with its depiction of skeletal and dental structures was introduced by Broadbent (1931) and Hofrath (1931), this marked the beginning of a new area in orthodontic diagnostics. Although profile photographs subsequently led a 'shadow' existence, new modes of analysis continued to be developed. In addition to the analysis of individual structures such as the lips [lip profile analyses according to Korkhaus (1939), Schwarz (1958), or Ricketts (1988)] or nose, there were also definitions of the facial thirds by Schwarz (1961) and descriptions of the profile using the jaw profile field (Schwarz, 1958), the H line (Holdaway, 1984), or the angle of facial convexity (Muzj, 1956; Burstone, 1958; Subtelny and Rochester, 1959).

More recently, computer-assisted analyses of facial photographs have received increasing attention. Edler *et al.* (2001, 2003, 2004) described the procedure for determining facial asymmetries on the basis of *en-face* photographs, especially of the mandibular region. They pointed out the advantage of non-invasiveness compared with dental tomographs. Another approach is non-invasive laser scanning of the face to obtain a computer-assisted three-dimensional image. These images are suitable not only for visualizing and diagnosing differences in static and functional occlusion (Kopp *et al.*, 2003), growth-related changes, and the results of orthodontic treatment (Kau *et al.*, 2004, 2005), but also for comparing various skeletal anomalies (Kau *et al.*, 2006). In this context, it is interesting to note which assertions can be made based on a profile photograph compared with a lateral cephalograph. Schwarz (1958) developed a procedure to describe an average or 'biomet' face based on a jaw profile field and reported that significant deviations from the facial type were associated with skeletal Class II and Class III subjects. Muzj (1956) also associated significant deviations from the normal profile as defined using the frontal-facial angle in skeletal Class II and Class III malocclusions, although he did not compare them to any measurements from a lateral cephalographs analysis.

The question is whether it is possible to determine the skeletal Class from a lateral (profile) photograph and which method of angle determination or analysis is the most suitable. The suitability of an analytical method in orthodontics depends on using concepts and structures that remain largely unaffected by growth. The literature frequently describes the 'facial angle of convexity excluding the nose', also called the 'facial contour angle', as stable (Subtelny, 1961; Mauchamp and Sassouni, 1973; Rakosi, 1979; Bishara *et al.*, 1985, 1998). Pelton and Elsasser (1955), however, found, in a cross-sectional study, that this angle was reduced during the growth process, with the reduction being more pronounced in girls than in boys. Subtelny and Rochester (1959), Mauchamp and Sassouni (1973), and Bishara *et al.* (1985, 1998) published long-term observations on patients with a normal profile and a neutral occlusion. While they observed a small increase in the angle of convexity, they considered this angle to be, on average, stable. Riolo *et al.* (1986) related the thickness of the soft tissues to body weight, finding no influence on the angle of convexity.

Muzj (1982) pointed out that analyses based on the Frankfort horizontal, such as the jaw profile field by Schwarz (1958), are prone to error. Slight positional changes at the ear point result in a noticeably changed evaluation of the facial profile. Moreover, physiological facial asymmetries yield different results, depending on whether the left or right side is examined. He therefore proposed a method for analyses based on the frontal-facial angle that is independent of sides and ear points. This angle corresponds largely to the angle of convexity.

The angle of convexity therefore appears to be the most suitable parameter in this regard, however, it has been defined differently by various authors, who use either the soft tissue glabella point (Gl′; Burstone, 1958; Mauchamp and Sassouni, 1973; Chaconas and Bartroff, 1975; Bishara *et al.*, 1985, 1998), a frontal point (Fr; Muzj, 1982) akin to the trichion point, an N′ point located directly in front of the palpable frontomaxillary suture (Pelton and Elsasser, 1955; Rakosi, 1979), an NS point defined on the lateral cephalographs by extending the Ba–N line (Subtelny, 1961), or an N′ point located at the bottom of the depression above the nose (Phillips *et al.*, 1984; Satravaha and Schlegel, 1987; Zylinski *et al.*, 1992; Ngan *et al.*, 1996; Ruf and Pancherz, 1999) as cranial reference points. By way of comparison, Figure 1 shows those points that were used in the present study. The central reference point used was either the subnasal point (Sn) at the transition from the nasal columella to the upper lip (Pelton and Elsasser, 1955; Burstone, 1958; Subtelny and Rochester, 1959; Mauchamp and Sassouni, 1973; Rakosi, 1979; Muzj, 1982; Satravaha and Schlegel, 1987; Zylinski *et al.*, 1992; Ngan *et al.*, 1996, Ruf and Pancherz, 1999) or the deepest point of the concavity of the upper lip described as A′ (Bowker and Meredith, 1959) or superior labial sulcus (SLs; Phillips *et al.*, 1984; Bishara *et al.*, 1985, 1998). The caudal reference point is sometimes the soft tissue gnathion point (Gn′; Muzj, 1956), but more frequently the soft tissue pogonion point (Pog′; Pelton and Elsasser, 1955; Burstone, 1958; Subtelny and Rochester, 1959; Merrifield, 1966; Mauchamp and Sassouni, 1973; Rakosi, 1979; Bishara *et al.*, 1985, 1998; Satravaha and Schlegel, 1987; Zylinski *et al.*, 1992; Ngan *et al.*, 1996; Ruf and Pancherz, 1999). Given this broad spectrum of different approaches regarding the profile angle, an additional question, over and above the main question, is whether it is possible to determine the skeletal Class from a lateral (profile) photograph and which reference point of the angle of convexity is most suitable for this purpose.

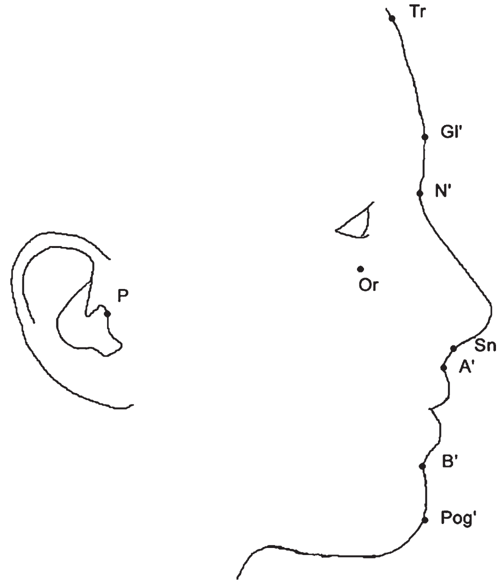

Figure 1 Schematic drawing of measuring points Or, P, Tr, Gl′, N′, A′, Sn, B′, Pog′.

Materials and methods

Patient data from 180 subjects treated in a specialist orthodontic practice were examined retrospectively. The inclusion criteria were a lateral cephalograph and a profile photograph of good quality taken on the same day. The lateral cephalograph was used to determine the Wits value according to Jacobson (1975) for classification of the patients as skeletal Class I, II, or III. For male patients, skeletal Class I included Wits values of between –1 and +2 mm, while the range for female patients was between 0 and + 2mm. Larger values were categorized as skeletal Class II and smaller values as skeletal Class III (Jacobson, 1975; Table 1). The mean age for the three skeletal Classes was between 11.7 and 13.6 years, with Class III, at 11.7 years, differing from the other two Classes at 13.6 years for both. This was due to the fact that the treatment of a skeletal Class III subject frequently commences earlier than that of a skeletal Class I or II subject.

The following soft tissue measuring points were determined by drawing lines on the profile photograph: trichion (Tr), glabella (Gl′), nasion (N′), subnasal point (Sn), superior labial sulcus (SLs or A′), inferior labial sulcus (ILs or B′), pogonion (Pog′), porion (P), and orbital (Or) (Figure 1). Based on these points, the following version of the angle of convexity were measured: N′SnPog′, N′A′Pog′, TrSnPog′, TrA′Pog′, Gl′SnPog′, and Gl′A′Pog′. A′OrB′ (=POrA′–POrB′) and A′N′B′ were also measured for comparison. The points and angles of 24 randomly selected cases (eight per skeletal Class) were re-analysed after no less than 3 and no more than 6 months (mean: 4.2 months). The combined method error was calculated using the formula $MF = \sqrt{(\Sigma d^2/2n)}$ (Dahlberg, 1940), where d represents the difference between measurements and n the number of double measurements. Soft tissue ANB (A′N′B′) exhibited the lowest value at 0.55 degrees and TrSnPog′ the highest value at 1.71 degrees. Measurement of the other angles yielded a method error of between 1.07 (N′SnPog′) and 1.37 (Gl′SnPog′) degrees. Other error values were 1.14 degrees for Gl′A′Pog′, 1.17 degrees for TrA′Pog′, 1.27 degrees for N′A′Pog′, and 1.34 degrees for A′OrB′.

A deviation from the normal distribution could not be determined for the individual classes and angles based on a Kolmogorov–Smirnov test at the 0.05 level. It was therefore possible to obtain statistical comparison using a two-sided *t*-test for independent samples. To test the skeletal Class assignment for accuracy based on the different profile angles, a linear discriminant analysis was additionally performed using the JMP statistical software (SAS Institute Inc., 2003).

Table 1 Classification according to Jacobson (1975). Wits values; including population sizes and sex distributions as well as the means and standard deviations for age.

	Wits	*n*	Male/female	Age (years)
Class I	–1 to +2 mm (m) 0 to +2 mm (f)	58	22/36	13.63 ± 2.14
Class II	Less than 2 mm	60	37/23	13.60 ± 2.62
Class III	More than –1 mm (m) Less than 0 mm (f)	62	28/34	11.65 ± 3.26

Discriminant analysis is a method of predicting one-way classification based on known values of the responses. The technique is based on how close a set of measurement variables are to the multivariate means of the levels being predicted.

Results

Table 2 shows the results for the three skeletal groups and the various angles and the P values obtained with the *t*-test. The highly significant differences ($P < 0.001$) between all angles for Class II and Class III and almost all angles for Class II and Class III are evident, the only exception in the latter case being A′N′B′, where the level of significance was only $P < 0.05$. The differences between Class I and Class II were statistically much less significant for all angles. Only N′SnPog′ and TrA′Pog′, and the two angles on the soft tissue glabella point, Gl′SnPog′, and Gl′A′Pog′, showed statistically significant differences at the 0.5 level.

The results of the linear discriminant analysis are summarized in Table 3. The assignment to skeletal Class I, II, and III based on angles A′N′B′ and A′OrB′ showed error rates of more than 50 per cent for both angles. The most unreliable assignments for these angles were those for Class I, which were only correct 27.6 and 17.2 per cent of the time, respectively. When A′N′B′ angle was used, the assignment to Class II and Class III were both almost 60 per cent correct, whereas A′OrB′ angle showed 46.7 per cent correct assignments to Class II and 64.5 per cent correct assignments to Class III. The percentages of incorrect assignments to the various classes based on the other angles were between 38.9 per cent and 45.6 per cent. The lowest margin of error, with correct assignments of between 75.8 per cent and 85.5 per cent was found for Class III, followed by Class II with between 55 and 58.3 per cent correct assignments, and Class I with between 27.6 and 46.6 per cent correct assignments. Assignments using angles touching point A′ were more frequently correct (GlA′Pog′, 38.9%; TrA′Pog′, 40%; N′A′Pog′, 40.6%) than

Table 2 Results for angles A′N′B′, A′OrB′ (=POrA′–POrB′), N′SnPog′, N′A′Pog′, TrSnPog′, TrA′Pog′, Gl′SnPog′, and Gl′A′Pog′ for the respective skeletal Classes including the 95 per cent confidence intervals.

Classes	I	II	III	I/II	I/III	II/III
A′N′B′	5.08 (4.57–5.60)	5.77 (5.03–6.23)	4.19 (3.69–4.69)	0.0654	0.0148	<0.001
A′OrB′	24.29 (22.94–25.65)	24.98 (23.74–26.21)	20.37 (19.06–21.68)	0.4801	<0.001	<0.001
N′SnPog′	165.73 (164.11–167.34)	162.87 (161.13–164.60)	172.97 (171.41–174.53)	0.0136	<0.001	<0.001
N′A′Pog′	166.96 (165.36–168.57)	164.83 (163.15–166.52)	174.65 (173.11–176.20)	0.0627	<0.001	<0.001
TrSnPog′	163.69 (162.05–165.33)	161.47 (159.77–163.17)	173.66 (172.07–175.24)	0.0576	<0.001	<0.001
TrA′Pog′	165.15 (163.52–166.79)	162.41 (160.64–164.18)	174.53 (172.96–176.12)	0.0193	<0.001	<0.001
Gl′SnPog′	167.19 (165.64–168.74)	164.81 (163.02–166.61)	175.49 (173.99–176.99)	0.0327	<0.001	<0.001
Gl′A′Pog′	168.05 (166.52–169.57)	165.65 (163.92–167.37)	176.63 (175.16–178.10)	0.0278	<0.001	<0.001

The last three columns show the P values obtained by statistical analysis using the *t*-test for unconnected samples for intergroup comparisons.

Table 3 Results of the linear discriminant analysis including absolute values and percentages.

	A′N′B′	A′OrB′	N′SnPog′	N′A′Pog′	TrSnPog′	TrA′Pog′	GlSnPog′	GlA′Pog′
Incorrect Class assignment	92 (51.1%)	102 (56.7%)	73 (40.6%)	73 (40.6%)	82 (45.6%)	72 (40.0%)	75 (41.7%)	70 (38.9%)
Correctly assigned to Class I	16 (27.6%)	10 (17.2%)	27 (46.6%)	26 (44.8%)	16 (27.6%)	24 (41.4%)	22 (37.9%)	24 (41.4%)
Correctly assigned to Class II	35 (58.3%)	28 (46.7%)	33 (55.0%)	33 (55.0%)	35 (58.3%)	34 (56.7%)	33 (55.0%)	33 (55.0%)
Correctly assigned to Class III	37 (59.6%)	40 (64.5%)	47 (75.8%)	48 (77.4%)	47 (75.8%)	50 (80.7%)	50 (80.7%)	53 (85.5%)
Class I misassigned to Class II	21 (36.2%)	30 (51.7%)	21 (36.2%)	21 (36.2%)	30 (51.7%)	25 (43.1%)	23 (39.7%)	25 (43.1%)
Class I misassigned to Class III	21 (36.2%)	18 (31.0%)	10 (17.8%)	11 (19.0%)	12 (20.7%)	9 (15.5%)	13 (22.4%)	9 (15.5%)
Class II misassigned to Class I	7 (11.7%)	17 (28.3%)	19 (31.7%)	17 (28.3%)	15 (25.0%)	16 (26.7%)	17 (28.3%)	18 (30.0%)
Class II misassigned to Class III	18 (30.0%)	15 (25.0%)	8 (13.3%)	10 (16.7%)	10 (16.7%)	10 (16.7%)	10 (16.7%)	9 (15.0%)
Class III misassigned to Class I	8 (12.9%)	9 (14.5%)	13 (21.0%)	11 (17.7%)	11 (17.7%)	11 (17.7%)	10 (16.1%)	8 (12.9%)
Class III misassigned to Class II	17 (27.4%)	13 (21.0%)	2 (3.2%)	3 (4.8%)	4 (6.5%)	1 (1.61%)	2 (3.2%)	1 (1.6%)

assignments using angles touching point Sn (N′SnPog′, 40.6%; GlSnPog′, 41.7%; TrSnPog′, 45.6%).

Discussion

This research examined whether it was possible to determine the skeletal Class from a lateral (profile) photograph and which angle was the most suitable to use.

Differences between soft tissue profile angles for the various skeletal Classes have rarely been described in the literature. Muzj (1956) reported a normal range of 174–177 degrees for his frontal-facial angle (faciocranial angle, Fr–Sn–Gn′). The ranges of 173–174 degrees and 177.5–179 degrees were defined by him as ‘paranormal’, while less than 173 and more than 179 degrees were ‘extranormal’ in that they represented skeletal Class II and Class III, respectively. However that author placed much greater weight on the symmetry of the two sides of the angle relative to its bisector that runs along the mandibular base. If the symmetry was impaired, a disharmony or anomaly was considered to be present that should be treated (Muzj 1956, 1982, 1983, 1985a,b, 1988). A comparison of these values with the measurements obtained in the present study is not possible, since the construction of Muzj’s frontal-facial angle was related to the mandibular base determined on a lateral cephalograph. Starting from there, the frontal point, Fr, is identified and defined as the highest and most anterior point of the cerebral cranium. Caudally, Gn is used as a reference. The soft tissue profile points are determined based on these bone-based points (Blafer, 1971).

Of the angles examined in the present investigation, TrSnPog′ was closest to that described by Muzj. The values found in this study for Class I and Class II were markedly below those reported by Muzj. As the Pog′ point used was located further anteriorly than Muzj’s Gn′ point, one would, conversely, have expected higher values. One explanation might be the different cranial points of reference, with the Fr point used by Muzj not being the same as the trichion used in the present study, although, based on the descriptions by Muzj (1956, 1982), the Fr point is presumably located in the vicinity of the hairline. Although the subjects differed greatly in age (Muzj developed his method predominantly with adult subjects, while the mean age in this research was 12.9 years), this would not explain the differences found; while a slight increase in the angle of convexity has been described throughout adolescence, a long-term comparison would still have to be based on the assumption that the proportions are stable (Subtelny and Rochester, 1959; Bishara *et al.*, 1985, 1998).

Other authors have reported only mean values for the angle of convexity and its variants (Pelton and Elsasser, 1955; Satravaha and Schlegel, 1987), or they examined only subjects with a ‘fair face’ (Burstone, 1958; Zylinski *et al.*, 1992), orthoocclusion (Mauchamp and Sassouni, 1973; Bishara *et al.*, 1985, 1998) or skeletal Class I (Subtelny and Rochester, 1959). Consequently, the results can only be compared with the measurements for skeletal Class I in the present investigation. Satravaha and Schlegel (1987) as well as Zylinski *et al.* (1992) determined the angle of convexity based on the N′, Sn, and Pog′ points. A comparison with the corresponding angle in the present subject population therefore appears feasible. Zylinski *et al.* (1992) reported the mean value for children aged 5–10 years with a ‘handsome’ face, a harmonious profile, competent lips, and ‘normal’ overbite and overjet as 163.3 degrees, varying between the extremes of 154.2 and 170.9 degrees; for adults aged 20–32 years meeting the same description, the corresponding values were 166 degrees (153.4–175.9 degrees). Both the mean value found in this study, namely 165.8 degrees, and the mean age of 13.7 years fall within this range and would therefore confirm those authors’ results, while giving rise to the assumption of a slight growth-related enlargement (Subtelny and Rochester, 1959; Mauchamp and Sassouni, 1973). Satravaha and Schlegel (1987) compared female Asian profiles, obtaining values between 164.6 and 165.9 degrees; however, there is no information related to intercuspation or profile. Subtelny and Rochester (1959) used NS point, located slightly further cranially than N′ point, for their angular measurements, obtaining mean values of 161.4 degrees for male and 161.0 degrees for female 14 year olds (skeletal Class I, no orthodontic treatment). Pelton and Elsasser (1955) reported that a cross-sectional study including more than 8400 subjects yielded mean values of between 162 and 166.5 degrees. Burstone (1958) found a mean GlSnPog′ angle of 168.7 degrees (extremes: 155.5 and 179.5 degrees) in young adults with a 'good face'. Mauchamp and Sassouni (1973) reported values of 168 degrees (male) and 165 degrees (female) for subjects aged 13.5 years. The results of the present study largely support these findings. The same is true for the studies of Bishara *et al.* (1985, 1998), who reported GlA′Pog′ angles of between 166.9 and 168.8 degrees for boys with an acceptable occlusion.

The answer to the question as to which profile angle is most suitable for assigning the correct skeletal Class would have to be based on the statistically significant differences between the various angles along with the results of a linear discrimination analysis. No statistically significant differences at the 0.01 level were found between Classes I and II for any angle, while N′SnPog′, TrA′Pog′, GlA′Pog′, and GlSnPog′ differed at the 0.05 level. The values for the other angles were sometimes considerably higher. By contrast, the good discrimination between skeletal Class I and Class III and between Class II and Class III were particularly salient.

One possible explanation is the lack of discrimination between divisions 1 and 2. The soft tissue profile points are clearly influenced by the underlying bony and dental structures, in this case including anterior tooth inclinations (Subtelny, 1961), which creates an inhomogeneity within the group that makes it difficult to construct a line between this and skeletal Class I. The high levels of significance when discriminating between Class I and Class III and between Class II and Class III can be explained by the large number of cases ($n = 180$).

Linear discriminant analysis showed the lowest error rate for GlA′Pog′, again followed by TrA′Pog′, N′A′Pog′, and N′SnPog′. What is interesting about these results is that angles containing A′ yielded better results with regard to the statistical differences with linear discriminant analysis and angles containing point Sn in the middle. One possible explanation might be the variations in the location of point Sn itself, which is conditioned by the morphology of the nose. This aspect was not separately taken into consideration in the measurements. By contrast, nasal morphology has very little influence on the location of point A′.

It is important for angular measurements to allow discrimination between the various skeletal Classes, but it is also important that the angle used allows maximum repeat accuracy. The method error was determined based on the analysis of Dahlberg (1940). This error, at between 1.07 and 1.17 degrees for N′SnPog′, GlA′Pog′, and TrA′Pog′, was low compared with other soft tissue angles, but still high compared with soft tissue ANB (0.55 degrees) and to skeletal measurements using lateral cephalographs with error rates of between 0.5 and 0.7 degrees (Kinzinger and Dietrich, 2005).

Another important issue is stability throughout the adolescent growth period. Pelton and Elsasser (1955), Subtelny and Rochester (1959), Mauchamp and Sassouni (1973), Zylinski *et al.* (1992), and Bishara *et al.* (1998) found variations in the angle of convexity, with Pelton and Elsasser (1955) reporting a reduction of the angle as growth progresses, while the other authors describe a slight increase. Subtelny and Rochester (1959) and Bishara *et al.* (1985, 1998) opined that the angle remained on average stable.

Conclusions

The angles of convexity most suitable for determining skeletal Class are N′SnPog′, GlA′Pog′, and TrA′Pog′, as these featured the smallest methodical errors, sufficient stability, and the highest discrimination between skeletal classes.

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