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Facial Flatness Indices: A Comparison of Two Methods of Assessment

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ABSTRACT

Objectives: The objective of the study was to evaluate and compare facial flatness indices calculated from the trigonometric formula as opposed to those generated from the direct measurements on three-dimensional radiographs.

Material and Methods: A total of 322 cone-beam computed tomography radiographs were digitized and three facial indices (frontal, simotic, and zygomaxillary) were assessed in two different methods and compared between different groups.

Results: There was a discrepancy between facial flatness indices generated from the two different approaches. The highest difference was seen in the findings of the simotic index and the lowest for the zygomaxillary index. No statistically significant difference was displayed in the three formula-generated flatness indices between males and females and between growing and non-growing subjects ($P > 0.05$). The zygomaxillary index was the only measurement revealing no statistically significant difference in Class III sagittal malocclusions ($t = -0.5$ $P = 0.621$). The orthodontic application would yield to the same interpretations for both ways of indices calculation.

Conclusion: The validity of the trigonometric formula used to appraise facial flatness indices might be questionable. The zygomaxillary index could be more clinically considered compared to the frontal and simotic indices.

Keywords: Facial flatness indices, Trigonometric formula, Validity of measurements

INTRODUCTION

The craniofacial characters, more precisely frontal and facial flatness, have changed during the human evolution and craniofacial dimensions have been altered throughout the years to produce the traits identified in the most recent groups and the modern populations.[1]

Facial flatness measures were introduced in anthropology to provide significant information concerning facial skeletal morphology. However, various measurements have been used to evaluate frontal and facial flatness in different populations to compare modern to ancient human beings.[2] In 1934, Woo and Morant evaluated facial flatness on dry skulls and subsequently, many anthropologists have used their method with minor modifications.

Consequently, facial flatness indices proposed by Yamaguchi[3] in 1973 have been used in anthropology for discrimination among populations. Three measurements were advocated: The frontal index, the simotic index (described by Woo and Morant in 1934),[4] and the zygomaxillary index (described by Alekseev and Debets in 1964).[5] These indices consisted of ratios between the projections of nasion (frontal subtense), median ridge of the nasalia (simotic subtense), and subspinale (zygomaxillary subtense) over the widths of the head (frontal), nose (simotic), and midface (zygomaxillary). The smaller the ratio value, the flatter the face.

The facial flatness indices have only been used in anthropology to evaluate disparities among populations. Hence, all these facial measurements were performed on dry skulls and their calculation resulted from a trigonometric formula.

In a previous recent study,[6] we used and applied the facial flatness indices on three-dimensional radiographs and the subtenses were measured through direct projections over the chords. The objective was to use these indices to assess flatness among orthodontic patients.

The purpose of this study was to evaluate and compare the appraisal of facial flatness indices through the subtenses resulting from the trigonometric formula (as in anthropology) as opposed to subtenses issued from the direct projections of digitized cone-beam computed tomography (CBCT) radiographs.

MATERIAL AND METHODS

Study population

The pre-treatment CBCT radiographs of 322 orthodontic patients (201 females and 121 males) were selected from the database of initial orthodontic records in a private radiologic center.

Excluded were subjects who had previous or current orthodontic treatment, craniofacial anomalies, or low-quality pre-treatment CBCT.

Before data collection, the study was approved by the Institutional Review Board of the American University of Beirut (IRB ID: BIO-2018-0065) that waived the need for consent form.

To evaluate the association between the facial indices' measurements and gender, growth, and malocclusion, female patients older than 16 years and males older than 18 years were classified as non-growing ($n = 78$), the remaining 244 were considered as growing.

As for the sagittal malocclusion, the ANB angle was used to classify the patients into three groups:
Class I: 0≤ANB≤4 ($n = 161$)
Class II: ANB > 4 ($n = 136$)
Class III: ANB < 0 ($n = 25$)

Radiographic analysis

The digitization of all CBCTs was conducted by one operator (CC) using the View Box 4 imaging software (dHAL Software, Kifissia, Greece).

Nine points were localized on CBCTs as illustrated in Figure 1:

1. Frontomalare orbitale right (fmo1) and left (fmo2): Defined as the junction of the frontozygomatic suture and the orbit rim.[7]
2. Nasion (n): Defined as the suture between the frontal and nasal bones.[8]
3. Deepest point on the lateral wall of nasal bone right (n1) and left (n2).[4]
4. Nearest point of the median ridge of the nasal bone (n').[4]
5. Zygomaxillary anterius right (zma1) and left (zma2): Defined as the most inferior point on the zygomaxillary suture.[7]
6. Subspinale (ss) or point A: Defined as the deepest midline point on the premaxilla between the anterior nasal spine and prosthion.[8]

Three facial indices (frontal, simotic, and zygomaxillary) were computed as follows [Figure 2]:

- Frontal index: Defined as the percentage of the nasion subtense to the chord between the frontomalaria orbitalia [Figure 2a].
- Simotic index: Defined as the percentage of the minimum subtense of the median ridge of the nasalia to the simotic chord (minimum horizontal breadth of the nasalia) [Figure 2b].
- Zygomaxillary index: Defined as the percentage of subspinale subtense to the chord between the zygomaxillaria anteriora [Figure 2c].

The subtenses were obtained by direct measurements of the projections of the distance from the summit to the chord and generated automatically from the View Box 4 imaging software.

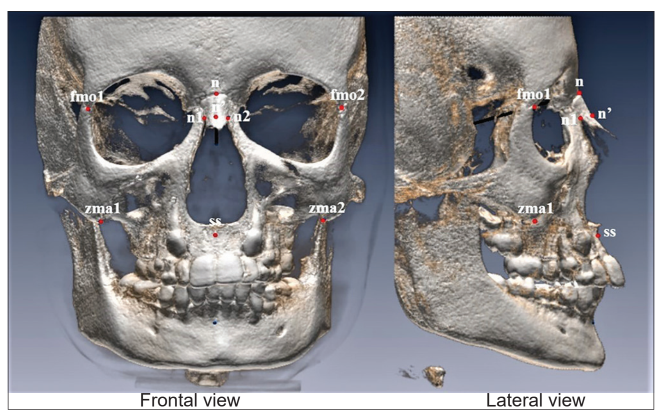

Figure 1: Digitized points from frontal and lateral views. *fmo1*: Right frontomalare orbitale; *fmo2*: Left frontomalare orbitale; *n*: Nasion; *n1*: Right deepest point on the lateral wall of nasal bone; *n2*: Left deepest point on the lateral wall of the nasal bone; *n'*: Nearest point of the median ridge of the nasal bone; *zma1*: Right zygomaxillary anterius; *zma2*: Left zygomaxillary anterius; ss: Subspinale.

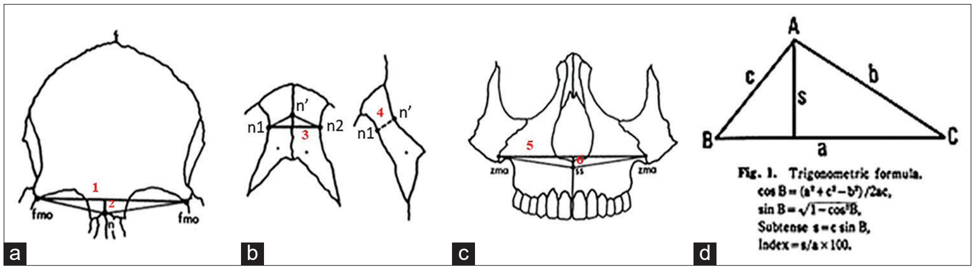

Figure 2: 1. Frontal chord; 2. Frontal subtense; 3. Simotic chord; 4. Simotic subtense; 5. Zygomaxillary chord; 6. Zygomaxillary subtense. a: Frontal index: Denominator: The frontal chord between the frontomalaria orbitalia, numerator: The subtense of the nasion from the frontal chord. b: Simotic index: Denominator: The simotic chord (the minimum horizontal breadth of the nasal bone), numerator: Simotic subtense (the minimum distance from the median ridge of the nasal bone to the simotic chord). c: Zygomaxillary index: Denominator: The zygomaxillary chord between the zygomaxillaria anteriora, numerator: Zygomaxillary subtense (distance from the subspinale to the zygomaxillary chord). d: Trigonometric formula according to the indices were calculated.

In addition, the computation of facial indices according to the trigonometric formula [Figure 2d] had necessitated the performance of three angular measurements [Figure 3]:

1- Fmo2-fmo1-n angle: The angle formed between fmo1-fmo2 and fmo1-n distances
2- Zma2- zma 1-ss angle: The angle formed between zma1-zma 2 and zma1-ss distances
3- n2-n1-n’ angle: The angle formed between n1-n2 and n1- n’ distances

The facial indices were calculated again according to the following trigonometric formula:

$$\text{Facial flatness index} = (\text{Subtense}/\text{Chord}) \times 100$$

$$\text{Subtense} = \text{side of the triangle} \times \sin(\text{basal angle})$$

To quantify the measurement error, a randomly chosen group of 30 CBCTs was redigitized by the same examiner and the intrarater reliability was assessed.

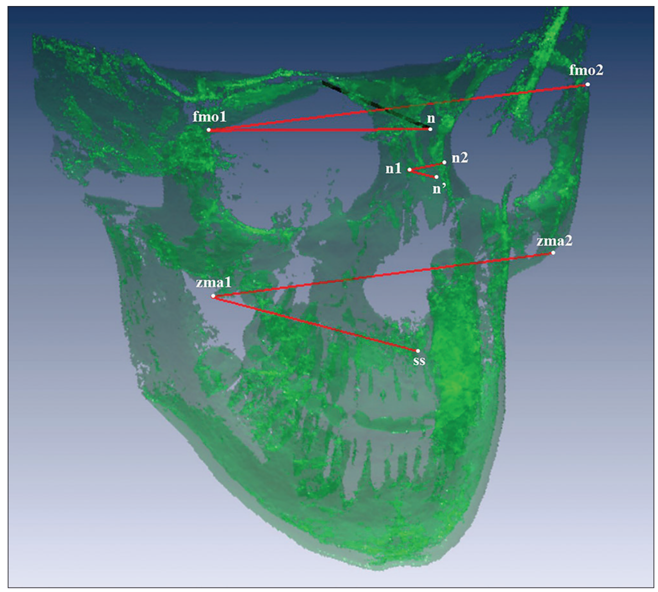

Figure 3: Illustration of the three basal angles of the three triangles measured on cone-beam computerized tomography radiographs for the calculation of the facial flatness indices according to the trigonometric formula. Basal angles: *n-fmo1-fmo2; n’-n1-n2; ss-zma1-zma2.* Chords: fmo1-fmo2; n1-n2; zma1-zma2. Sides of the triangle used for each facial index: n-fmo1; n’-n1; ss-zma1.

Statistical analysis

Descriptive data were generated for the outcome variable and its indicators. Means and their standard deviations for all the measured components were calculated.

A three-way between subjects analysis of variance (ANOVA) was used to assess the presence of interaction between gender (male and female), growth (growing and adult), and malocclusion (Classes I, II, and III) on the facial flatness indices and to compare the different groups.

The paired *t*-test was applied to assess the differences between facial flatness indices calculated with the direct projection measurement of the subtenses and the values generated from the trigonometric formula.

The repeated measures were evaluated with the two-way mixed effects intraclass correlations for absolute agreement on single measures. The same test was applied to investigate the reliability of the two methods in assessing facial flatness using the three facial indices.

Data were processed through the Statistical Package for the Social Sciences (SPSS®, version 23.0, IBM®) and Stata/SE™ 11.1. Statistical significance was set at 0.05.

RESULTS

Reliability of the measurements

Intraclass correlation coefficients calculated for the intrarater reliability ranged between 0.82 and 0.99.

Sexual dimorphism

None of the three formula-generated indices displayed a statistically significant difference between males and females, regardless of malocclusion and growth ($P > 0.05$, Table 1).

Effect of growth

There was no statistically significant difference in the three formula-generated flatness indices when assessing the main effect of growth ($P > 0.05$; Table 1).

Effect of sagittal malocclusion

When comparing the formula-generated flatness indices among the three malocclusion groups (Classes I, II, and III), there was no statistically significant difference in the frontal (F = 5.445, P = 0.922) and simotic (F = 0.107, P = 0.899) indices.

Only the zygomaxillary index displayed a significant difference among malocclusions (F = 5.43, P = 0.005), it was significantly larger in Class II (32.12 ± 0.64 mm) than Class I (29.77 ± 0.46 mm) followed by Class III (29.08 ± 1 mm) [Table 1].

Correlations

Moderate positive correlations were detected: The formula-generated zygomaxillary index demonstrated the highest intraclass correlation coefficients compared with the formula-generated frontal and simotic indices [Table 2].

Comparison of the direct and formula-generated facial flatness indices

There was a statistically significant difference in the three formula-generated flatness indices when calculating the subtenses according to the trigonometric formula in comparison with the calculation of the subtenses through the direct projections to the chords.

This difference was noticed in the total sample, in female and male groups, in growing and non-growing subjects and sagittal malocclusions as well [Tables 3 and 4].

Table 1: Difference in formula-generated measurements of facial indices between different subgroups.

	FI		SI		ZI	
	EMM	SE	EMM	SE	Mean	SE
Males (*n*=121)	21.94	0.37	47.16	1.9	30.78	0.68
Females (*n*=201)	21.34	0.28	44.37	1.44	29.88	0.51
F (*P*)	10.057 (0.703)		1.368 (0.243)		1.119 (0.291)	
Growing (*n*=244)	21.74	0.22	44.5	1.14	31.04	0.41
Non-growing (*n*=78)	21.55	0.41	47.03	2.09	29.61	0.75
F (*P*)	1.017 (0.172)		1.126 (0.289)		2.812 (0.095)	
Class I (*n*=161)	21.85	0.25	46.4	1.29	29.77[a]	0.46
Class II (*n*=136)	21.28	0.35	45.54	1.79	32.12[a,b]	0.64
Class III (*n*=25)	21.79	0.55	45.36	2.82	29.08[b]	1
F (*P*)	5.445 (0.922)		0.107 (0.899)		5.43 (0.005)*	

FI: Frontal index; SI: Simotic index; ZI: Zygomaxillary index; EMM: Estimated marginal mean; SE: Standard error. Alphabetic subscripts denote significantly different means at P<0.05 (*Post hoc* Bonferroni correction). *Statistically significant, P<0.01

Table 2: Intraclass correlation coefficient between the direct and formula-generated measurements in the total sample and subgroups.

	FI		SI		ZI	
	ICC	*P*	ICC	*P*	ICC	*P*
Total	0.501	<0.001**	0.58	<0.001**	0.618	<0.001**
Growing	0.510	<0.001**	0.575	<0.001**	0.771	<0.001**
Non-growing	0.465	<0.001**	0.592	<0.001**	0.398	0.011*
Males	0.451	<0.001**	0.652	<0.001**	0.746	<0.001**
Females	0.532	<0.001**	0.529	<0.001**	0.565	<0.001**
Class I	0.558	<0.001**	0.627	<0.001**	0.541	<0.001**
Class II	0.449	<0.001**	0.548	<0.001**	0.696	<0.001**
Class III	0.318	0.011*	0.282	0.001**	0.652	0.007**

ICC: Two-way mixed effects intraclass correlations for absolute agreement on average measures. FI: Frontal index; SI: Simotic index; ZI: Zygomaxillary index. *Statistically significant, P<0.05; **statistically significant. P<0.01

Table 3: Comparison between the direct and formula-generated frontal index (FI) and simotic index (SI) in the total sample and subgroups.

	FI SI direct projection of subtense		FI SI formula-generated subtense		Difference (D-F) FI SI		Paired *t*-test FI SI	
	Mean	SD	Mean	SD	Mean	SD	t	*p*
Total sample	18.35	2.68	21.49	2.45	−3.14	0.13	−24.09	<0.001**
	59.83	12.24	45.18	12.52	14.65	0.54	27.13	<0.001**
Males	18.42	2.63	21.92	2.35	−3.5	2.29	−16.77	<0.001**
	59.89	12.65	45.18	13.51	14.71	8.52	18.99	<0.001**
Females	18.30	2.71	21.24	2.48	−2.93	2.35	−17.69	<0.001**
	59.79	12.02	45.18	11.92	14.61	10.35	20.01	<0.001**
Growing	18.57	2.50	21.60	2.36	−3.03	0.14	−22.03	<0.001**
	59.22	12.32	44.89	12.78	14.33	0.66	21.83	<0.001**
Non-growing	17.66	3.08	21.15	2.71	−3.49	0.32	−10.84	<0.001**
	61.72	11.87	46.08	11.69	15.64	0.86	18.13	<0.001**
Class I	18.37	2.84	21.68	2.51	−3.31	0.17	−19.59	<0.001**
	59.68	13.06	45.03	13.51	14.64	0.76	19.17	<0.001**
Class II	18.35	2.57	21.21	2.41	−2.86	0.22	−13.09	<0.001**
	59.89	12.12	45.47	12.05	14.42	0.87	16.53	<0.001**
Class III	18.17	2.21	21.80	2.17	−3.64	0.46	−7.87	<0.001**
	60.44	6.33	44.54	7.96	15.9	1.34	11.83	<0.001**

FI: Frontal index, SI: Simotic index. **Statistically significant. $P<0.01$

Table 4: Comparison between the direct and formula-generated zygomaxillary (ZI) index in the total sample and subgroups.

	ZI direct projection of subtense		ZI formula-generated subtense		Difference (D-F)		Paired *t*-test	
	Mean	SD	Mean	SD	Mean	SD	t	*p*
Total sample	31.94	3.16	30.72	4.64	1.22	0.23	5.34	<0.001**
Males	32.28	3.12	31.41	3.37	0.87	2.85	3.36	0.001
Females	31.73	3.17	30.30	5.23	1.43	4.68	4.32	<0.001**
Growing	32.29	3.05	31.22	3.11	1.07	0.16	6.62	<0.001**
Non-growing	30.83	3.26	29.14	7.49	1.69	0.8	2.12	0.037*
Class I	31.52	2.98	30.06	5.59	1.46	0.39	3.73	<0.001**
Class II	32.92	3.14	31.69	3.15	1.22	0.25	4.9	<0.001**
Class III	29.33	2.25	29.66	3.90	−0.32	0.65	−0.5	0.621

ZI: Zygomaxillary index. *Statistically significant, $P<0.05$; **statistically significant. $P<0.01$

The only difference that was not statistically significant was related to the zygomaxillary index in Class III sagittal malocclusions [Table 4].

The frontal index was larger when calculated with the trigonometric formula compared with the direct measurements [Table 3], whereas the simotic and the zygomaxillary indices revealed decreased outcomes when deliberated from the same formula [Tables 3 and 4].

The largest differences were observed in the simotic index results [Table 3] and the lowest differences were seen for the zygomaxillary index [Table 4].

DISCUSSION

Throughout the years, series of measurements on human cranium had been used to assess facial flatness at different levels of the face and some features related to facial flatness were the subject of interpopulation phylogenetic variations.[9,10]

Yamaguchi[3] described three indices to evaluate facial flatness and used them only on dry skulls. The calculation of these indices was based on a trigonometric formula, whereby the subtense of each index was deliberated by the multiplication of the sinus of the basal angle of the relative triangle by the adjacent side.

It is well known that the introduction of CBCT had its increasing impact on diagnosis and treatment planning in dentistry.[11-15] Furthermore, it is advantageous to be used in analyzing facial flatness in all dimensions. The accuracy and reproducibility of measurements of CBCT of a human dry skull were proved statistically highly correlated.[16,17] Accordingly, 3D CBCT imaging shall allow the appraisal of outcomes heretofore drawn from separate anthropologic studies performed on human skulls.

The outcomes of the formula-generated facial indices calculated in this study were concomitants with those deliberated from the direct measurements in the previous paper[6] for the total group and the various subgroups. Consequently, their interpretations and applications in orthodontic field would have been the same.

On the other hand, the comparison of the facial flatness indices generated from the subtenses assessed through its direct projections to the opposite chords with the subtenses created from the trigonometric formula had yield to statistically different means. The biggest differences were seen for the simotic index although the same triangle was used for the calculation. Concerning the zygomaxillary index, the differences in the findings were the least. While this divergence in the zygomaxillary index was statistically significant, its clinical implication would be highly important and considerable.

In general, the discrepancy in the outcomes of the three indices would allow to question the validity of the trigonometric formula. To note that there were no studies in the literature comparing the formula used in many anthropological studies to the direct measurements issued from CBCTs.

Therefore, it is advisable as a future project to test the accuracy of the trigonometric formula anthropologically determined by calculating it from the CBCTs of the same dry skulls.

CONCLUSION

1. The rationality of facial flatness indices generated from the trigonometric formula is questionable.
2. The discrepancy between the facial flatness indices produced by the calculation of the subtenses as direct projections to the chords and those created by the calculation of the subtenses from the trigonometric formula was the highest for the simotic index and the lowest for the zygomaxillary index.
3. Although the difference of the findings was statistically significant for the zygomatic index, its clinical impact would be more substantial.
4. The application of facial flatness indices in orthodontic field would lead to the same interpretation but with a difference of the facial indices normal means.

Declaration of patient consent

Institutional Review Board (IRB) permission obtained for the study.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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