BDS Brazilian Dental Science
Ciência Odontológica Brasileira

unesp
UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Instituto de Ciência e Tecnologia
Campus de São José dos Campos

ORIGINAL ARTICLE

doi: 10.14295/bds.2015.v18i2.1092

Photographic assessment of hyperdivergent skeletal Class II patients

Avaliação fotográfica de pacientes padrão esquelético classe II hiperdivergentes

Liliane Rosas GOMES[1], Karla Orfelina Carpio HORTA[2], Luiz Gonzaga GANDINI JÚNIOR[1], Marcelo GONÇALVES[3], João Roberto GONÇALVES[1]

1 – Department of Orthodontics and Pediatric Dentistry – FACULDADE DE ODONTOLOGIA DE ARARAQUARA – UNESP Univ Estadual Paulista – Araraquara – São Paulo – Brazil.

2 – Private practice – Ribeirão Preto – Sao Paulo – Brazil.

3 – Department of Diagnosis and Surgery – FACULDADE DE ODONTOLOGIA DE ARARAQUARA – UNESP Univ Estadual Paulista – Araraquara – São Paulo – Brazil

ABSTRACT

Temporomandibular disorders, sleep disturbances by airway obstruction and craniocervical posture changes constitute some of the problems that have been related to hyperdivergent skeletal Class II patients. Although cephalometric radiographs represent the gold standard for diagnosing craniofacial morphology in clinical practice, it might not be feasible for large-scale epidemiological research. **Objectives:** The aim of this study was to test the validity of a new photographic method in diagnosing hyperdivergent skeletal Class II patients for epidemiological research purposes. **Material and Methods:** Lateral cephalograms and profile photographs were obtained from 123 subjects assigned into two groups. 51 patients comprised the hyperdivergent skeletal Class II group and the other 72 composed a second group. Discriminant analysis described a mathematical model to better diagnose hyperdivergent skeletal Class II patients through photographs. **Results:** A canonical discriminant function composed of two photographic variables correctly classified 85% of the hyperdivergent skeletal Class II patients during internal validation ($p < 0.001$). The method showed 83% sensitivity and 73% specificity in external validation procedure. **Conclusion:** The photographic method may be a feasible and practical alternative for diagnosing the hyperdivergent skeletal Class II patient, particularly if there is a need for a low-cost and noninvasive method.

KEYWORDS

Malocclusion, Angle Class II, hyperdivergent; Epidemiologic methods; Photography; Retrognathia.

RESUMO

Desordens temporomandibulares, distúrbios do sono por obstrução das vias aéreas e alterações na postura crânio-cervical constituem alguns dos problemas que têm sido relacionados com o paciente padrão esquelético classe II hiperdivergente. Embora as telerradiografias laterais representem o padrão ouro para o diagnóstico da morfologia craniofacial na prática clínica, este exame pode não ser viável para aplicação em estudos epidemiológicos de larga escala. **Objetivo:** O objetivo deste estudo foi testar a validade de um novo método fotográfico no diagnóstico de pacientes classe II hiperdivergentes para fins de investigação epidemiológica. **Material e Métodos:** Telerradiografias laterais e fotografias de perfil foram obtidas a partir de 123 indivíduos distribuídos em dois grupos: 51 pacientes compuseram o grupo de pacientes classe II hiperdivergente, enquanto que os outros 72 pacientes formaram um segundo grupo. A análise discriminante descreveu um modelo matemático para melhor diagnosticar pacientes padrão esquelético classe II hiperdivergente através de fotografias. **Resultados:** Uma função canônica discriminante composta por duas variáveis fotográficas classificou corretamente 85% dos pacientes classe II hiperdivergentes durante a validação interna ($p < 0{,}001$). O método mostrou 83% de sensibilidade e 73% de especificidade no processo de validação externa. **Conclusão:** O método fotográfico pode ser considerado como uma alternativa viável e prática para diagnosticar o paciente classe II hiperdivergente, particularmente se existir a necessidade de um método não invasivo e de baixo custo.

PALAVRAS-CHAVE

Má Oclusão de Angle Classe II, hiperdivergente; Métodos epidemiológicos; Fotografia; Retrognatismo.

INTRODUCTION

Hyperdivergent skeletal Class II patients have been related to abnormal physiological conditions. It has been shown that specific craniofacial features such as increased anterior facial height [1-2], reduced mandibular ramus height [1-3], greater inclination of the mandible and occlusal plane relative to cranial base [1,2], reduced forward growth of the maxillomandibular complex [3] and reduced mandibular corpus length [1-3] are linked to temporomandibular joint (TMJ) internal derangement.

Raised position of the head and forward inclination of the cervical column were also related to long-face morphology and retrognathic profile [4-6]. Moreover, the hyperdivergent skeletal Class II patient has been associated with higher prevalence and severity of sleep disturbances by airway obstruction [7]. However, the cause and effect relationship among such particular skeletal type and these abnormal conditions is still unclear, which has increased investigators' interest to address these issues in longitudinal epidemiological studies.

Although cephalometric radiographs constitute the gold standard for diagnosing craniofacial morphology in clinical practice, it might not be feasible for large-scale epidemiological studies [8]. Noninvasive alternatives have been suggested in order to establish an accurate diagnosis without radiation exposure [9], and the use of standardized photographs has been investigated as a simple, quick, low-cost and low-tech needs procedure, i.e., a feasible alternative to lateral cephalograms for preliminary diagnosis [8-11].

The aim of this study was to test the validity of a new photographic method in diagnosing hyperdivergent skeletal class II patients, and determine a group of measurements that was the most suitable for this purpose.

MATERIAL AND METHODS

Lateral cephalograms and standardized profile photographs both taken in natural head position (mirror position) were obtained from a sample of 123 subjects, 65 girls and 58 boys, aged between 7 and 12 years (Mean age 8.9 yrs, SD 1.4). The inclusion criteria were as follows: no previous orthodontic or surgical treatment, all six maxillary anterior teeth present, no craniofacial or cervical trauma, no congenital anomalies and no neurological disturbances. The sample comprised children admitted for the treatment of various malocclusions at Araraquara Dental School, UNESP or at some of the partner institutions. Thus, lateral radiographs had been already required as part of the initial orthodontic records. Parents or legal guardians were previously informed about the procedures and gave their written agreement to the investigation. The study was approved under the protocol nº 66/10, by the local Committee of Ethics.

Digital photographic and radiographic records were analyzed with Radiocef® 2.0 (Radio Memory Ltda., Belo Horizonte, MG, Brazil) software for Windows. Through cephalometric analysis, children were divided into two groups according to skeletal sagittal and vertical relationships accessed by ANB and SN.GoMe angles respectively. 51 patients, 22 boys and 29 girls, formed the hyperdivergent skeletal Class II group (ANB > 4.5º and SN.GoMe > 36º) and the other 72 subjects, 36 boys and 36 girls (ANB ≤ 4.5º and SN.GoMe ≤ 36º) composed the second group. Detailed description of our photographic and radiographic protocol is given in a previous paper [12].

Anatomical landmarks used in this investigation are shown in Figure 1. A specific analysis was previously customized in the software using the landmarks defined for the purpose of this study. Traditional cephalometric angular and linear measurements (Figure 2) and analogous photographic ones were used for sagittal and vertical assessment as well as for craniocervical posture analysis (Figures 3 and 4). The software automatically calculated all the measurements once the landmarks were properly identified on each record, which had previously been scaled to life size. Computerized evaluation of facial morphology through radiographs and photographs were performed by the same operator in a blind design.

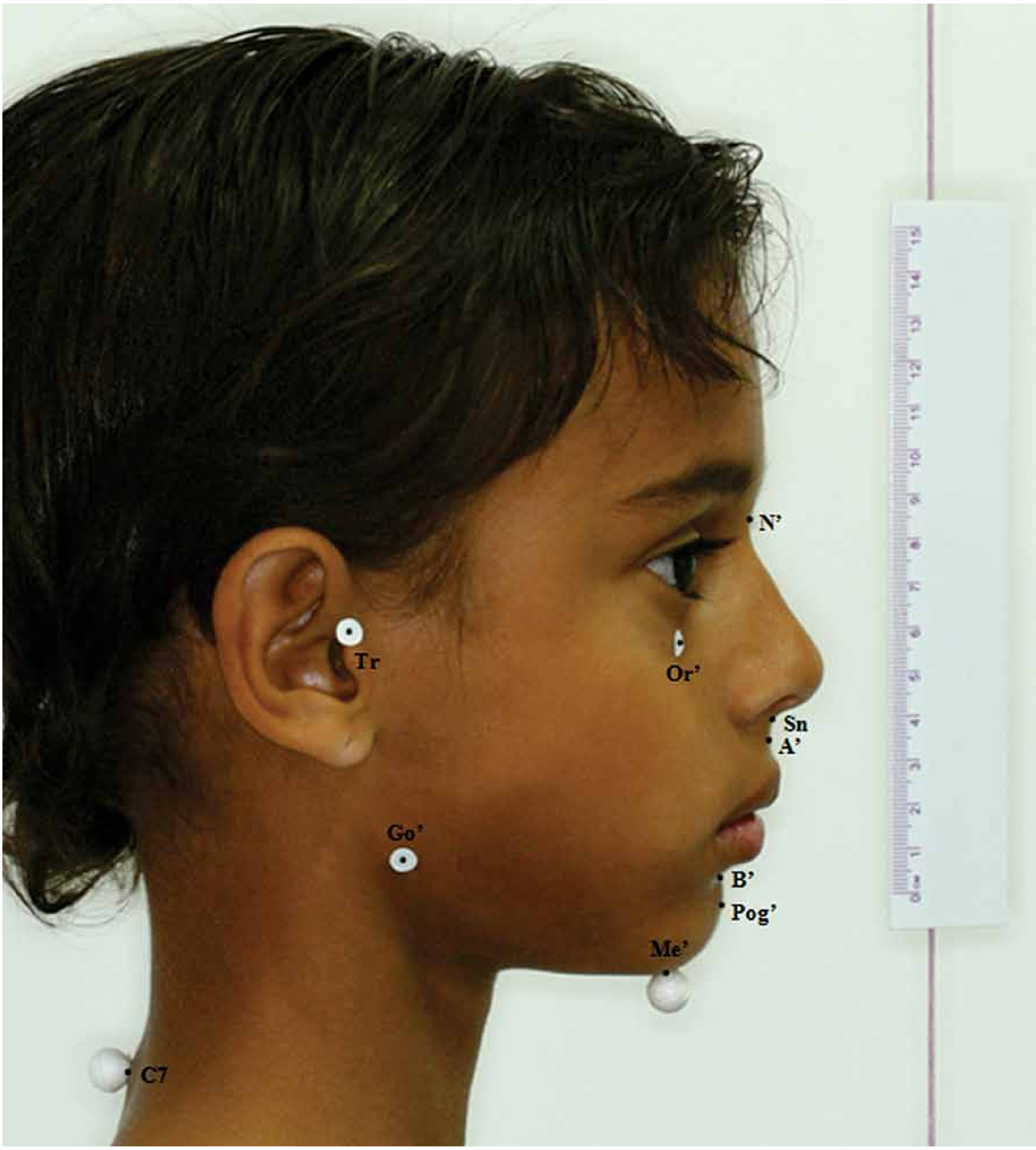

Figure 1 - Photographic landmarks. N', Soft-tissue Nasion; Tr, Tragion; Or', Soft-tissue Orbitale; A', Soft-tissue Subspinale; B', Soft-tissue Supramentale; Go', Soft-tissue Gonion; Pog', Soft-tissue Pogonion; Me', Soft-tissue Menton; Sn, Subnasale, C7, seventh cervical spinous process tip. Adhesive dots or styrofoam beads were placed on the anatomical landmarks identified by palpation: Or', Tr, Go', Me' and C7.

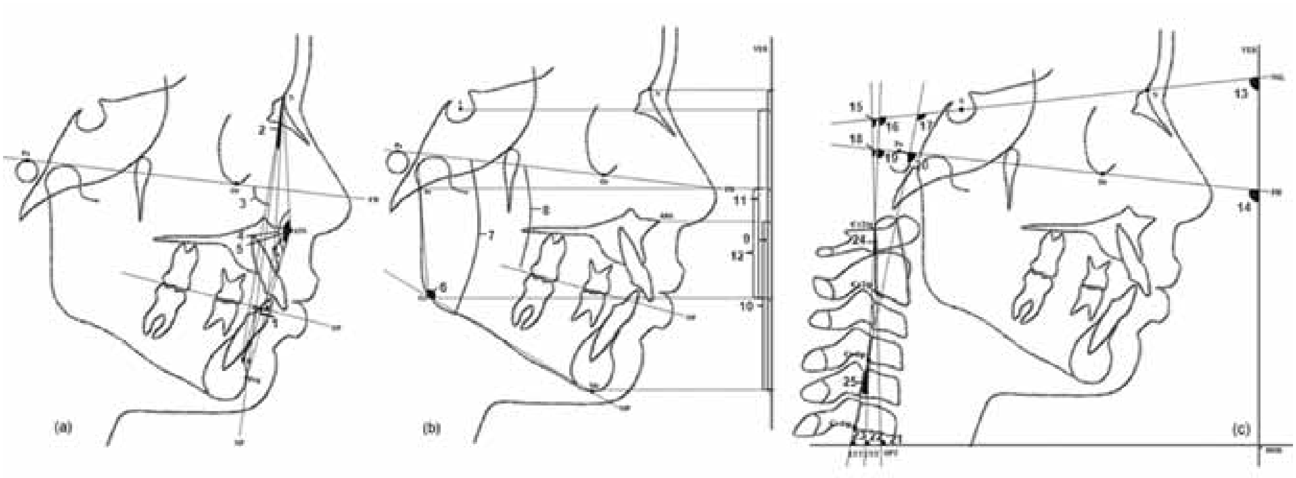

Figure 2 - Cephalometric measurements. (a) Sagittal assessment: (1) Wits, maxillomandibular linear discrepancy; (2) ANB, maxillomandibular angular discrepancy; (3) FNP, facial angle; (4) N.ANS.Pog, (5) N.ANS.B, angles of facial convexity. (b) Vertical assessment: (6) Ar.Go.Me, gonial angle; (7) FMA, Frankfurt to mandibular plane angle; (8) OPA, Frankfurt to occlusal plane angle; (9) AFH (N-Me), anterior facial height; (10) LAFH (ANS-Me), lower anterior facial height; (11) PFH (S-Go), posterior facial height; (12) LPFH (Ar-Go), lower posterior facial height. (c) Head and cervical posture assessment: (13) NSL.VER, (14) FH.VER, craniovertical angles; (15) NSL.OPT, (16) NSL.CVT, (17) NSL.EVT, (18) FH.OPT, (19) FH.CVT, (20) FH.EVT, craniocervical angles; (21) OPT.HOR, (22) CVT.HOR, (23) EVT.HOR, cervicohorizontal angles; (24) OPT.CVT, (25) CVT.EVT, cervical lordosis angles.

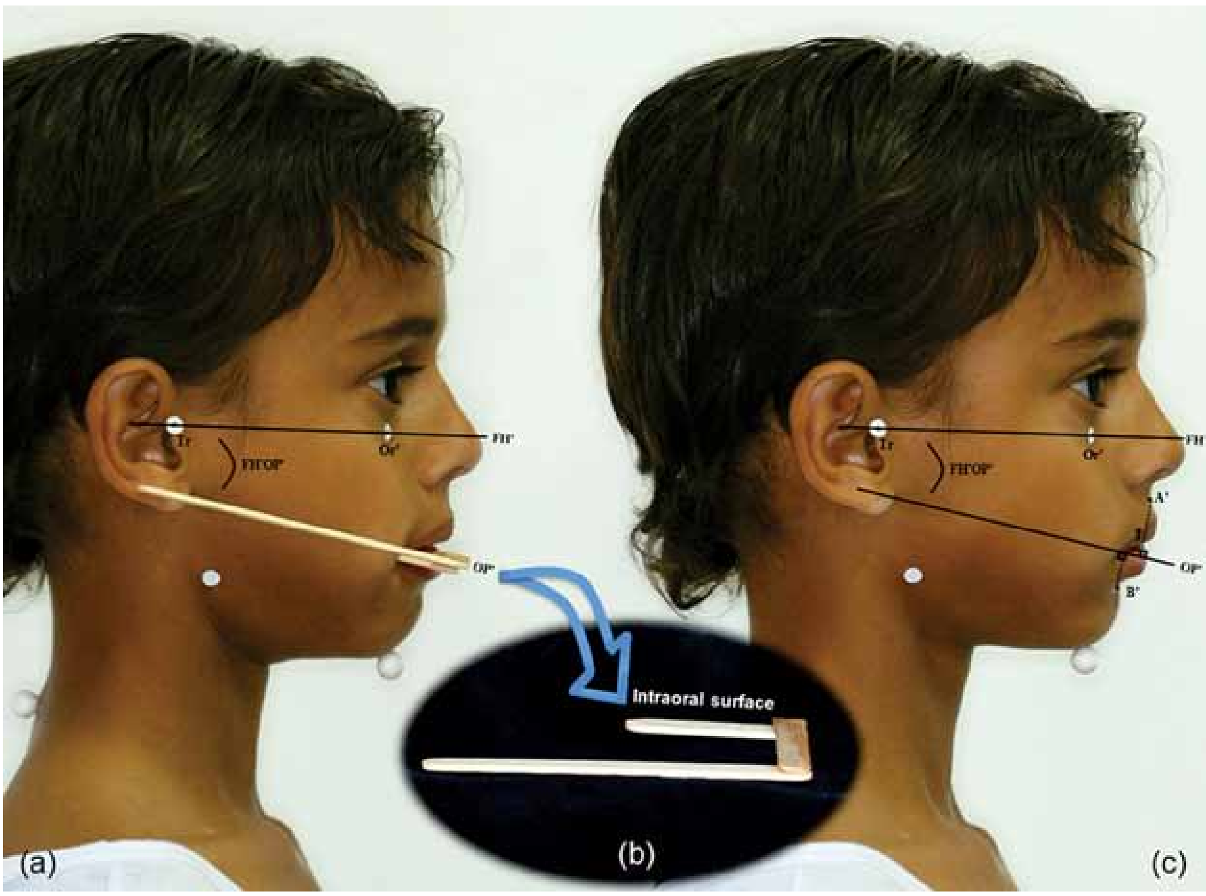

Figure 3 - Photographic measurements. Sagittal assessment: (1) Wits', soft-tissue maxillomandibular linear discrepancy. (a) patient occluding a wooden spatulas device, (b) schematic representation of the device, (c) distance A'-B' obtained after the transfer of FH'OP' angle to the photography held in maximum intercuspation.

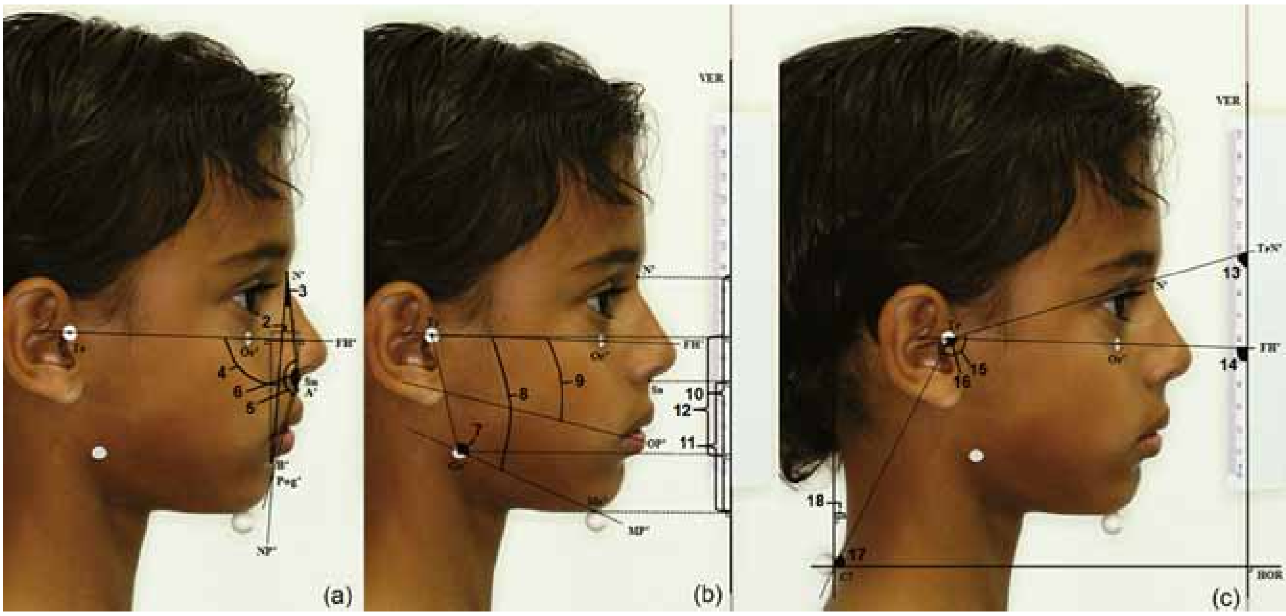

Figure 4 - Photographic measurements continuation. (a) Sagittal assessment: (2) A'-B'perp, soft-tissue maxillomandibular linear discrepancy; (3) A'N'B', soft-tissue maxillomandibular angular discrepancy; (4) FNP', soft-tissue facial angle; (5) N'.Sn.Pog', (6) N'.Sn.B', soft-tissue angles of facial convexity. (b) Vertical assessment: (7) Tr.Go'.Me', soft-tissue gonial angle; (8) FMA', soft-tissue Frankfurt to mandibular plane angle; (9) OPA', soft-tissue Frankfurt to occlusal plane angle; (10) AFH' (N'-Me'), soft-tissue anterior facial height; (11) LAFH' (Sn-Me'), soft-tissue lower anterior facial height; (12) PFH' (Tr-Go'), soft-tissue posterior facial height. (c) Head and cervical posture assessment: (13) TrN'.VER, (14) FH'.VER, craniovertical angles; (15) C7.TrN', (16) C7.FH', craniocervical angles; (17) TrC7.HOR, cervicohorizontal angle; (18) CL, cervical lordosis assessed by the sagittal distance between the lowest point of the cervical spine lordosis toward the true vertical passing through C7 point.

Method error

Repeatability analysis was carried out on a sample of 27 subjects (15 males and 12 females) randomly selected. After a 1-week interval, adhesive dots were replaced by the same rater on the anatomical landmarks identified by palpation. Then, another picture was taken. Reproducibility analysis was also conducted on a sample of 20 subjects (9 males and 11 females) randomly selected. Hence, a second rater repeated the landmark location by palpation and replaced the adhesives prior to taking the picture.

Statistical analysis

Data were subjected to statistical analysis using the Statistical Package for the Social Sciences (SPSS), version 16.0 (SPSS Inc Chicago, IL, USA). Descriptive statistics were obtained for each photographic variable used for assessing sagittal and vertical diagnosis, regarding the two different skeletal facial types subgroups. Means and standard deviations were also presented for both cephalometric and photographic head and cervical posture variables. Differences between the groups were evaluated by independent sample t-test. Intraclass correlation coefficients (ICC) were estimated from repeated photographic measurements to evaluate method repeatability and reproducibility. Analogous cephalometric and photographic measurements were compared to assess Pearson correlation coefficients.

Discriminant analysis was conducted to obtain, from a wide range of photographic variables, the smallest set of measurements that mostly discriminate the hyperdivergent skeletal Class II patient from the other skeletal patterns. Only variables which reached the level of significance in differentiating the groups were selected for the analysis. A canonical discriminant function was calculated by the stepwise procedure according to the method of Wilks. It was firstly included in the model the variable with the smallest value of Wilks' lambda, i. e., the one which seemed to discriminate the groups the most. Subsequent variables were chosen by lambda recalculation for each remaining variables. The F-test criterion was set at 3.84, which corresponds to a significance level of 5%. After each new variable was added to the discriminant function, variables already included in the model were re-assessed and dropped out if the F-test criterion was no longer satisfied. The stepwise operation continued until there were no further variables giving F-values greater than the F criterion, i.e., since they no longer contributed significantly to the predictive power of the discriminant function [13].

In order to carry out internal and external validation procedures, the whole sample was randomly subdivided into two groups. Approximately 70% of the total sample (n = 89, 39 hyperdivergent skeletal Class II, 50 other skeletal pattern) composed the calibration set, which was used to build the mathematical model and perform internal validation. The remaining sample (n = 34, 12 hyperdivergent skeletal Class II, 22 other skeletal pattern) formed the test set, which was used for external validation purposes.

RESULTS

Sagital measurements made over photographs showed high repeatability and reproducibility (ICC ≥ 0.90). Considering variables used for assessing vertical diagnosis, ICC were above 0.80. ICC ranged from 0.70 to 0.82 when evaluating head and cervical posture variables. Only cervical lordosis (CL) reproducibility showed a lower intraclass correlation coefficient (ICC = 0.51).

Table 1 summarizes descriptive statistics for sagittal and vertical photographic measurements,

Table 1 - Descriptive statistics for facial photographic measurements and differences between the groups by independent sample t-test

	Group I Hyperdivergent skeletal Class II (n = 51)				Group II Other skeletal pattern (n = 72)				Group I versus Group II	
Measurements	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**Sig.**
Sagittal assessment:										
Wits'	3.44	2.47	-1.90	9.71	1.50	3.13	-4.95	9.04	1.94	***
A'-B'perp	13.85	2.54	8.49	18.70	10.44	2.81	3.46	16.72	3.42	***
A'N'B'	10.62	1.66	7.71	13.98	8.53	1.98	3.97	13.33	2.09	***
FNP'	83.58	3.14	76.67	89.93	85.89	2.97	80.19	94.41	-2.30	***
N'.Sn.Pog'	158.01	4.04	150.12	168.15	163.41	5.02	152.39	176.38	-5.39	***
N'.Sn.B'	155.11	4.36	146.03	164.74	160.32	5.72	148.99	174.30	-5.20	***
Vertical assessment:										
Tr.Go'.Me'	133.23	5.02	123.84	143.98	131.12	5.70	116.89	142.26	2.10	*
FMA'	29.99	4.42	19.83	40.87	26.73	4.00	15.91	36.47	3.26	***
OPA'	18.85	4.25	7.22	26.25	16.73	3.45	7.27	23.49	2.12	**
LAFH' (Sn-Me')	59.17	3.57	52.43	68.15	58.93	4.02	49.80	68.84	0.24	NS
AFH' (N'-Me')	109.07	5.13	99.25	123.08	107.27	6.21	94.93	123.79	1.79	NS
PFH' (Tr-Go')	49.69	4.38	42.44	59.34	50.81	4.78	37.99	61.74	-1.11	NS
LAFH'/ AFH'	0.54	0.02	0.50	0.59	0.55	0.02	0.50	0.60	-0.01	NS
PFH'/ AFH'	0.45	0.04	0.40	0.56	0.47	0.04	0.38	0.56	-0.02	*
PFH'/ LAFH'	0.84	0.08	0.71	1.01	0.86	0.08	0.67	1.07	-0.02	NS

NS, Not significant; * p ≤ 0.05; ** p ≤ 0.01; *** p ≤ 0.001

regarding the different skeletal facial patterns. Significant differences ($p \leq 0.05$ to $p \leq 0.001$) were found between the hyperdivergent skeletal Class II and the other skeletal pattern groups for all sagittal and most vertical diagnostic variables.

Means and standard deviation for head and cervical posture cephalometric and photographic measurements are shown in Table 2. Significant differences between hyperdivergent skeletal Class II patients and the other skeletal patterns were observed for some cephalometric measurements ($p \leq 0.05$ to $p \leq 0.01$). Photographic variables did not show significant difference between the groups.

Table 2 - Descriptive statistics for cephalometric and photographic postural variables and differences between the groups by independent sample t-test

	Group I Hyperdivergent skeletal Class II (n = 51)		Group II Other skeletal pattern (n = 72)		Group I versus Group II	
Measurements	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**Sig.**
Cephalometric Assessment:						
Craniovertical angles						
NSL.VER	80.16	3.52	82.31	4.03	-2.15	**
FH.VER	91.57	3.33	92.16	3.61	-0.59	NS
Craniocervical angles						
NSL.CVT	100.67	8.27	97.69	7.84	2.98	*
NSL.OPT	98.08	9.46	94.47	8.79	3.61	*
NSL.EVT[a]	112.27	6.46	109.49	9.17	2.78	NS
FH.CVT	89.26	8.33	87.84	7.71	1.42	NS
FH.OPT	86.67	9.51	84.62	8.38	2.04	NS
FH.EVT[a]	100.83	6.39	99.38	9.14	1.45	NS
Cervicohorizontal angles						
CVT.HOR	89.17	7.53	90.00	7.14	-0.83	NS
OPT.HOR	91.77	8.54	93.22	8.08	-1.45	NS
EVT.HOR[a]	77.51	5.32	78.34	7.30	-0.83	NS
Cervical lordosis angles						
OPT.CVT	2.59	2.78	3.22	3.41	-0.63	NS
CVT.EVT[a]	12.71	9.29	12.86	10.11	-0.14	NS
Photographic Assessment:						
Craniovertical angles						
TrN'VER	71.74	2.92	72.48	3.56	-0.74	NS
FH'VER	86.44	3.18	86.97	3.65	-0.52	NS
Craniocervical angles						
C7TrN'	140.34	6.11	141.29	6.98	-0.95	NS
C7FH'	125.64	6.32	126.80	7.08	-1.16	NS
Cervicohorizontal angle						
TrC7HOR	57.92	4.85	56.23	5.36	1.69	NS
Cervical lordosis						
CL	6.90	2.13	6.77	2.86	0.12	NS

NS, Not significant; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

a Measurements which evolve the EVT line was performed on 96 patients (41 hyperdivergent skeletal Class II, 55 other skeletal pattern). The remaining sample did not present the sixth cervical vertebra visible on the radiograph.

It was found highly significant correlations between analogous cephalometric and photographic measurements ($p \leq 0.001$) for almost all sagittal and vertical diagnostic variables. Although most measures used for assessing head and cervical posture showed significant correlations with one another ($p \leq 0.05$ to $p \leq 0.001$), some of them did not. Given the entire sample, the highest coefficients were found between ANB versus A'N'B' (r = 0.82) and FMA versus FMA' (r = 0.81). The lowest significant one was found for NSL.OPT versus C7TrN' (r = 0.24) (Table 3).

The ten photographic variables which reached the level of significance in differentiating the groups (Table 1) were selected for Discriminant Analysis. The stepwise method firstly included in the model the variable A'-B'perp. Subsequently, N'.Sn.Pog' was selected. After the inclusion of FMA' in the model, variables already included were re-assessed and A'-B'perp was dropped out since the F-test criterion was no longer satisfied. Finally, A'N'B' was included in the model, which lead to the exclusion of N'.Sn.Pog' (Table 4). Therefore, A'N'B' and FMA' showed the highest discriminating power in combination and were used to formulate the following canonical discriminant function (D):

D = - 8.308 + (0.486 x A'N'B') + (0.130 x FMA')

It was found a satisfactory separation of the groups through the discriminant function ($p < 0.001$). "Group centroids", i. e., the mean values of the discriminant score for a given category were at 0.879 for the hyperdivergent skeletal Class II group, and -0.685 for the other group. Figure 5 shows scores distribution.

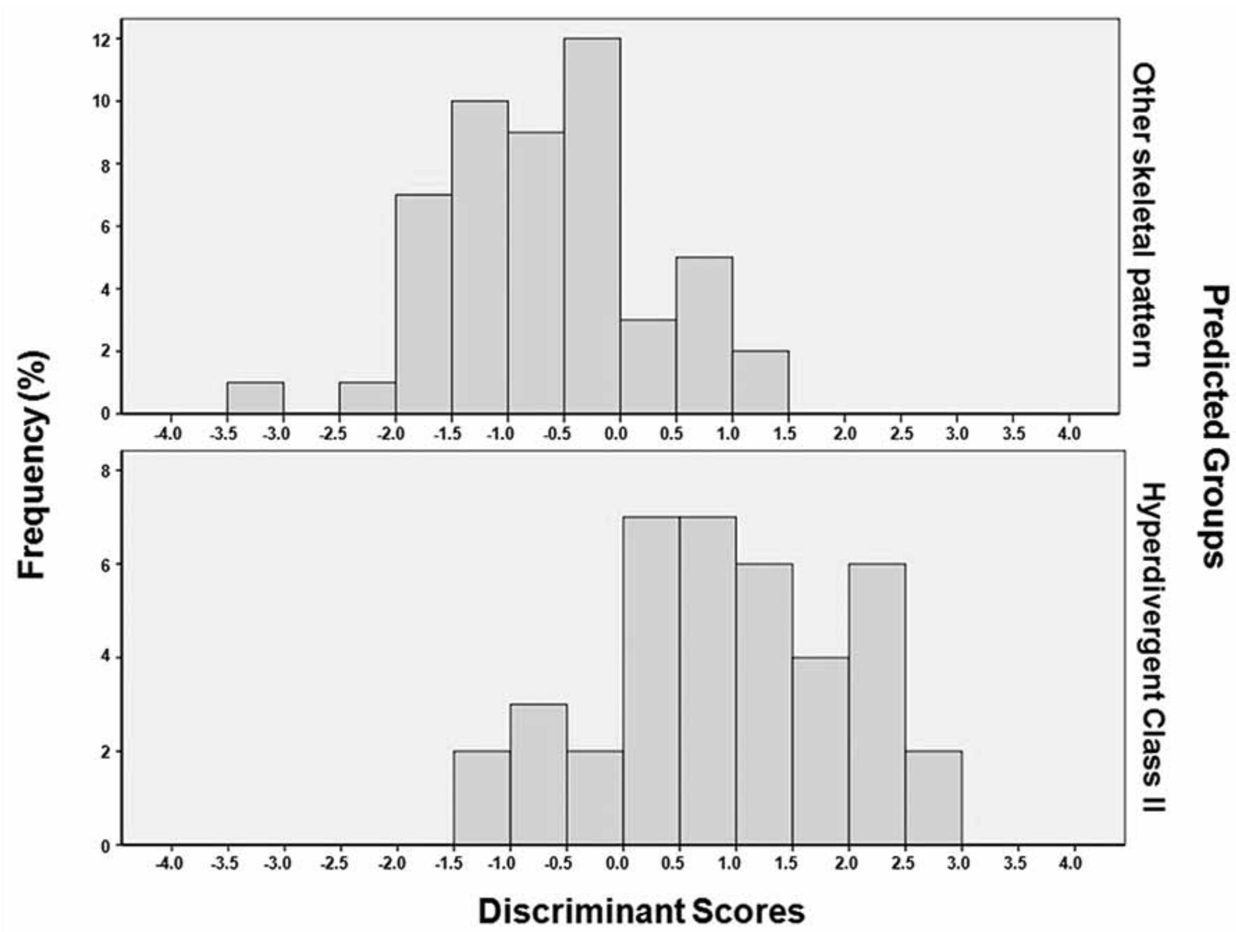

Figure 5 - Histograms showing the distribution of discriminant scores for hyperdivergent class II patient and the other skeletal patterns.

The cut-off point or "Z critical" was calculated after obtaining "centroids" values of the discriminant groups I (C1) and II (C2), divided by the sum of the number of observations in each group (N1 + N2), from the equation:

$$Z\ critical = (N2 \times C1) + (N1 \times C2) / (N1+N2)$$

$$= (50 \times 0.879) + (39 \times -0.685) / 89$$

$$= (43.95 - 26.715) / 89$$

$$= 17.235/ 89$$

$$= 0.2$$

D values greater than 0.2 indicated a hyperdivergent skeletal class II patient, whereas values lower or equal to 0.2 suggest that the patient presents other skeletal facial pattern. The method showed 79.5% sensitivity, 82% specificity, 77.5% positive predictive value and 85% negative predictive value, during the calibration set. When used for the test set, it presented 75% sensitivity, 77.3% specificity, positive and negative predictive values of 64.3% and 85% respectively.

Considering that the purpose of the present investigation was to develop a method for diagnosing the hyperdivergent skeletal Class II patient among other skeletal patterns, a receiver operating characteristic (ROC) curve was used to find the cut-off point that, besides showing great balance between sensitivity and specificity, preferably improves its sensitivity. Therefore, the final threshold value adopted as cut-off point for DA models was -0.2 (Figure 6). The method turned to evidence sensitivity of 84.6% and specificity of 74% during the calibration set (Table 5). When tested in another sample, the method showed 83.3% sensitivity and 72.7% specificity (Table VI). Figure 7 illustrates the results of the discriminant analysis given the total sample (n=123).

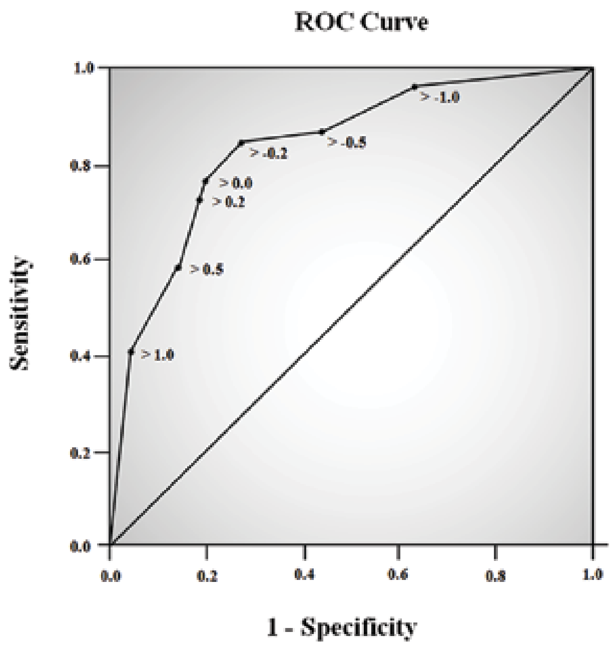

Figure 6 - ROC curve. Sensitivity is plotted against 1 minus specificity for different cut-off values given the total sample (n = 123).

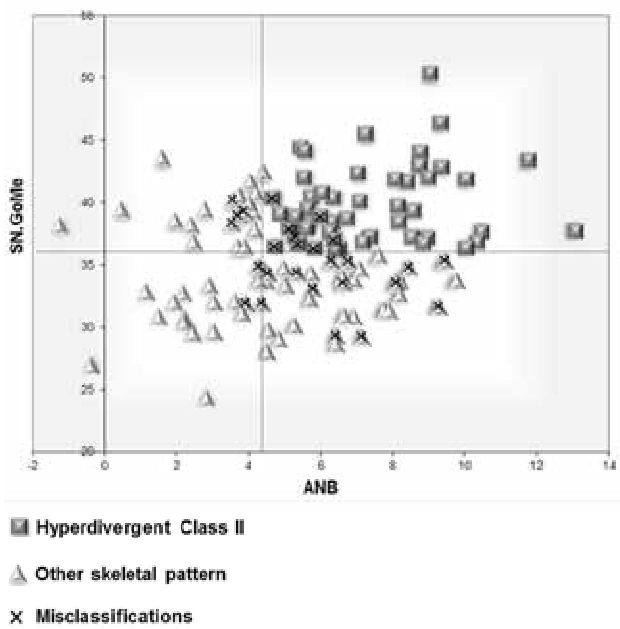

Figure 7 - Discriminant analysis results.

Table 3 - Correlation coefficients between cephalometric and photographic measurements

Measurement parameters		All subjects (n = 123)		Hyperdivergent skeletal Class II (n = 51)		Other skeletal pattern (n = 72)	
Cephalometric	Photographic	Correlation	Sig.	Correlation	Sig.	Correlation	Sig.
Sagittal Assessment:							
Wits	Wits'	0.73	***	0.51	***	0.79	***
Wits	A'-B'perp	0.61	***	0.39	**	0.60	***
ANB	A'N'B'	0.82	***	0.85	***	0.72	***
FNP	FNP'	0.61	***	0.62	***	0.48	***
N.ANS.Pog	N'.Sn.Pog'	0.68	***	0.60	***	0.58	***
N.ANS.B	N'.Sn.B'	0.69	***	0.53	***	0.64	***
Vertical Assessment:							
ArGoMe	Tr.Go'.Me'	0.79	***	0.69	***	0.83	***
FMA	FMA'	0.81	***	0.80	***	0.75	***
OPA	OPA'	0.72	***	0.69	***	0.69	***
LAFH (ANS-Me)	LAFH' (Sn-Me')	0.78	***	0.82	***	0.76	***
AFH (N-Me)	AFH' (N'-Me')	0.70	***	0.76	***	0.66	***
PFH (S-Go)	PFH' (Tr-Go')	0.49	***	0.50	***	0.53	***
LPFH (Ar-Go)	PFH' (Tr-Go')	0.53	***	0.41	**	0.52	***
LAFH/ AFH	LAFH'/ AFH'	0.63	***	0.56	***	0.68	***
PFH/ AFH	PFH'/ AFH'	0.47	***	0.47	***	0.40	***
LPFH/ LAFH	PFH'/ LAFH'	0.48	***	0.36	**	0.53	***
Head and cervical posture assessment:							
NSL.VER	TrN'VER	0.58	***	0.49	***	0.62	***
FH.VER	FH'VER	0.63	***	0.58	***	0.65	***
NSL.CVT	C7TrN'	0.33	***	0.17	NS	0.47	***
NSL.OPT	C7TrN'	0.24	**	0.10	NS	0.37	**
NSL.EVT[a]	C7TrN'	0.52	***	0.43	**	0.58	***
FH.CVT	C7FH'	0.35	***	0.25	NS	0.44	***
FH.OPT	C7FH'	0.25	**	0.16	NS	0.34	**
FH.EVT[a]	C7FH'	0.54	***	0.50	***	0.57	***
CVT.HOR	TrC7HOR	0.26	**	0.12	NS	0.38	***
OPT.HOR	TrC7HOR	0.16	NS	0.03	NS	0.28	*
EVT.HOR[a]	TrC7HOR	0.42	***	0.40	**	0.46	***
OPT.CVT	CL	0.25	**	0.10	NS	0.32	**
CVT.EVT[a]	CL	0.15	NS	0.34	*	0.04	NS
NSL.EVT[a]	CL	0.40	***	0.48	***	0.35	**
FH.EVT[a]	CL	0.37	***	0.46	**	0.32	*
EVT.HOR[a]	CL	-0.47	***	-0.52	***	-0.44	***

NS, Not significant; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

a Measurements which evolve the EVT line was performed on 96 patients (41 hyperdivergent skeletal Class II, 55 other skeletal pattern). The remaining sample did not present the sixth cervical vertebra visible on the radiograph.

Table 4 - Stepwise discriminant analysis

	Variables			Wilks' Lambda		
Step	**Entered**	**Removed**	**F to Remove**	**Statistic**	**df1**	**Sig.**
1	A'-B'perp		40.325	0.683	1	***
2	A'-B'perp		6.386	0.645	2	***
	N'.Sn.Pog'		5.074			
3	A'-B'perp	A'-B'perp	2.196	0.613	3	***
	N'.Sn.Pog'		6.940			
	FMA'		4.455			
4	N'.Sn.Pog'		32.052	0.629	2	***
	FMA'		8.780			
5	N'.Sn.Pog'	N'.Sn.Pog'	2.524	0.601	3	***
	FMA'		9.946			
	A'N'B'		3.962			
6	FMA'		12.103	0.619	2	***
	A'N'B'		33.992			

*** $p \leq 0.001$

Table 5 - Identification of hyperdivergent skeletal Class II patients by a canonical discriminant function: Calibration set

	Canonical discriminant function (D) diagnosis		
Cephalometric diagnosis (Gold standard)	**Hyperdivergent skeletal Class II (D > -0.2)**	**Other skeletal patterns (D ≤ -0.2)**	**Total**
Hyperdivergent skeletal Class II (ANB > 4.5°, SN.GoMe » 36°)	33 (84.6%)	6 (15.4%)	39 (100%)
Other skeletal patterns (ANB ≤ 4.5°, SN.GoMe ≤ 36°)	13 (26%)	37 (74%)	50 (100%)
Total	**46**	**43**	**89**
Sensitivity		TP/ (TP + FN) = 84.6%	
Specificity		TN/ (TN + FP) = 74%	
Positive predictive value		TP/ (TP + FP) = 71.7%	
Negative predictive value		TN/ (TN + FN) = 86%	
Total accuracy		TP+TN/ (TP + FN + TN + FP) = 78.7%	

D = - 8.308 + (0.486 x A'N'B') + (0.130 x FMA')
TP, true positive; TN, true negative; FP, false positive; FN, false negative

Table 6 - Identification of hyperdivergent skeletal Class II patients by a canonical discriminant function: Test set

	Canonical discriminant function (D) diagnosis		
Cephalometric diagnosis (Gold standard)	**Hyperdivergent skeletal Class II (D > -0.2)**	**Other skeletal patterns (D ≤ -0.2)**	**Total**
Hyperdivergent skeletal Class II (ANB > 4.5°, SN.GoMe » 36°)	10 (83.3%)	2 (16.7%)	12 (100%)
Other skeletal patterns (ANB ≤ 4.5°, SN.GoMe ≤ 36°)	6 (27.3%)	16 (72.7%)	22 (100%)
Total	**16**	**18**	**34**
Sensitivity		TP/ (TP + FN) = 83.3%	
Specificity		TN/ (TN + FP) = 72.7%	
Positive predictive value		TP/ (TP + FP) Ū62.5%	
Negative predictive value		TN/ (TN + FN) Ū 88.9%	
Total accuracy		TPŪTN/ (TP + FN + TN + FP) = 76.5%	

D= - 8.308 + (0.486 x A'N'B') + (0.130 x FMA')
TP, true positive; TN, true negative; FP, false positive; FN, false negative

DISCUSSION

Through repeatability and reproducibility tests, it was found that both linear and angular measurements useful for characterizing facial morphology can be reliably measured from facial photographs, which corroborates previous studies [8-12,14-18]. Regarding variables used for assessing head and cervical posture, ICC ranged from moderate to strong. This finding suggests that photography might be a reliable and practical alternative when radiography is considered too invasive or logistically impractical [8,12,17], however, care must be taken when considering postural variables.

Subjects, particularly children, found it uncomfortable to maintain the position while pictures were being taken, and tended to rest the head [18]. This may explain the fact that the ICC obtained for measurements that assessed head and cervical posture had lower values when compared to ones which are less dependent on patient collaboration. Other authors have found greater ICC values when evaluating posture in adolescents or adult patients [19,20].

Once this paper aimed to identify hyperdivergent skeletal Class II patients in the population, the second group was not limited to a single skeletal pattern, but comprised patients with different craniofacial features. Significant differences between the groups were found for most diagnostic variables, except for some linear measurements. This finding suggests that it is possible to distinguish the hyperdivergent skeletal Class II patient from the other skeletal types through most photographic measurements studied, mainly the angular ones. Conversely, there were no significant differences between the groups concerning any postural photographic measurements.

It was found highly statistically significant correlations ($p \leq 0.001$) for most analogous cephalometric and photographic measurements in this research, which agreed previous studies [8,9]. The strongest correlation coefficients were observed for ANB vs. A'N'B' and FMA vs. FMA'. However, our results corroborate statements that not all parts of the soft-tissues follow the skeletal structures linearly, which may explain the moderate correlation coefficients obtained [8,9,21,22].

Although sagittal and vertical jaw relationships were, in general, well reflected by the overlying soft-tissues (Pearson correlation coefficients ranged from moderate to strong), weak to moderate correlation coefficients were observed when comparing analogous postural measurements. Comparisons involving the upper cervical vertebra segment showed the lowest correlations. These findings may suggest that the overlying soft-tissue of the neck did not reflect the anatomic alignment of the cervical vertebrae, mainly the upper segment, which corroborates a previous report [19].

Out of the 21 photographic variables evaluated in the current study, 10 showed statistically significant differences between the groups and may be used for diagnostic purposes. Discriminant analysis was conducted as an attempt to find, among them, the best set of predictors in distinguishing the hyperdivergent skeletal Class II patient from the other skeletal patterns. Although A'-B'perp, N'.Sn.Pog' were shown to differentiate the groups, A'N'B' and FMA' variables presented the highest discriminative power when in combination.

The use of the discriminant function to predict group membership resulted in 85% of the patients being correctly classified, which ensured a satisfactory internal validation. When used for the external validation procedure, the discriminant model correctly classified 83% of hyperdivergent skeletal Class II subjects and 73% of the patients with other skeletal patterns. Moreover, it was found a negative predictive value of 89%, which means that when the predicted diagnosis is negative, there is great probability that the patient is not a hyperdivergent skeletal Class II indeed.

It was observed that most part of the misclassified patients were borderline subjects, i. e., patients who presented values of ANB and/or SN.GoMe close to the norm. Given this fact, it can be inferred that the use of photographic method for diagnosing severe cases may present even greater results.

Overall, the photographic method provided a good prediction model for detecting the hyperdivergent skeletal Class II patient. However, the results of this investigation corroborate previous findings in assuming that cephalometry remains the method of choice for clinical patient care [8]. Photographs might be better for large-scale epidemiological studies, especially when there is a need for a low-cost, noninvasive method [8].

CONCLUSION

- Highly statistically significant correlations between analogous photographic and cephalometric measurements were found for most sagittal and vertical diagnostic variables. Pearson correlation coefficients ranged from moderate to strong. However, caution is needed when inferring vertebral alignment from observed surface contours.
- A'N'B' and FMA' were the photographic measurements which showed higher discriminative power in combination.
- The photographic method may be considered a feasible and practical alternative for diagnosing the hyperdivergent skeletal Class II patient in large-scale epidemiological studies.

ACKNOWLEDGEMENTS

This work was supported by São Paulo Research Foundation, FAPESP, Brazil [Grant number 2012/02933-1]. The authors also gratefully acknowledge Radio Memory Ltda. for having generously provided the software Radiocef Studio version 2.0 for this research, and thank GESTOS and APCD academic institutions for the partnership.

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Liliane Rosas Gomes
(Corresponding address)
Faculdade de Odontologia de Araraquara, UNESP Univ Estadual Paulista, Departamento de Clínica Infantil, Rua Humaitá, 1680, Araraquara, São Paulo, Brasil.
CEP: 14801-903. Tel.: 55 71 8804-3200.
E-mail: lilianerosas@hotmail.com

Date submitted: 2014 Dec 30

Accept submission: 2015 May 11