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"Júlio de Mesquita Filho"
Faculdade de Odontologia de Araraquara

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Método fotográfico para diagnóstico do padrão esquelético facial e avaliação da postura crânio-cervical

Dissertação apresentada ao Programa de Pós-Graduação em Ciências Odontológicas - Área de Ortodontia, da Faculdade de Odontologia de Araraquara, da Universidade Estadual Paulista, para obtenção do título de Mestre em Ciências Odontológicas.

Orientador: Prof. Dr. João Roberto Gonçalves

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Dedicatória

Dedicatória

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Augusto Cury

Sumário

Sumário

Resumo

Gomes LCR. Método fotográfico para diagnóstico do padrão esquelético facial e avaliação postural [Dissertação de mestrado]. Araraquara: Faculdade de Odontologia da UNESP; 2012.

Resumo

Objetivos: O presente estudo teve como objetivo geral a descrição do método fotográfico, visando testar sua validade no diagnóstico do padrão esquelético facial e avaliação postural. Como objetivos específicos, buscou-se a investigação da relação existente entre medidas cefalométricas e fotográficas análogas, e a verificação da eficácia do método no diagnóstico do padrão esquelético classe II hiperdivergente e na avaliação da postura da cabeça e coluna cervical.

Materiais e Métodos: Dois artigos científicos foram elaborados e utilizados para a avaliação dos propósitos apresentados.

Resultados: Tanto a repetibilidade quanto a reprodutibilidade do método fotográfico foram satisfatórias. A maioria das mensurações apresentou ICC acima de 0,80. Verificaram-se correlações altamente significativas ($p \leq 0,001$) comparando a maioria das variáveis fotográficas com medidas cefalométricas análogas. Não foram encontradas correlações significativas para algumas variáveis posturais. Dentre todas as mensurações utilizadas, o ângulo A'N'B' foi o mais eficaz em explicar a variabilidade da medida cefalométrica correspondente, principalmente para indivíduos do gênero feminino (r^2 = 0,80). O ângulo FMA' apresentou os melhores resultados para a avaliação vertical (r^2 = 0,65). Uma função canônica discriminante composta por duas variáveis fotográficas (A'N'B', FMA') classificou corretamente 85% dos pacientes classe II hiperdivergentes durante a validação interna ($p < 0,001$). O método demonstrou sensibilidade de 83% e especificidade de 73% no processo de validação externa.

Conclusões: O método fotográfico pode ser considerado uma alternativa viável, prática e confiável para o diagnóstico de pacientes padrão esquelético classe II hiperdivergente em estudos epidemiológicos de larga escala, uma vez que um protocolo adequado de padronização da técnica seja seguido. É importante que haja cautela quando da inferência do alinhamento das vértebras cervicais a partir da análise de fotografias de perfil. Estudos adicionais são necessários a fim de testar a precisão do método no diagnóstico de outros padrões esqueléticos faciais.

PALAVRAS-CHAVE: Fotografia; Diagnóstico; Estudos de validação.

Abstract

Gomes LCR. Photographic method for skeletal pattern diagnosis and postural evaluation [Dissertação de mestrado]. Araraquara: Faculdade de Odontologia da UNESP; 2012.

Abstract

Objectives: The general purpose of this study was to describe the photographic method, in order to test its validity for the diagnosis of skeletal facial pattern and postural evaluations. The specific goals consisted on the investigation of the relationship between analogous cephalometric and photographic measurements, and the verification of method effectiveness in diagnosing the hyperdivergent class II patient and assessing the posture of the head and cervical column.

Materials and Methods: Two scientific papers were elaborated and used for assessing the purposes presented.

Results: The reliability of the photographic technique was satisfactory. Most measurements showed ICC above 0.80. It was found highly significant correlations ($p \leq 0.001$) for almost all analogous photographic and cephalometric variables. No significant correlations were found for some postural variables. Among all measurements used, A'N'B' angle was the most effective in explaining the variability of its analogous cephalometric, mainly for female subjects ($r^2 = 0.80$). FMA' angle showed the best results for vertical assessment ($r^2 = 0.65$). A canonical discriminant function composed of two photographic variables (A'N'B', FMA') correctly classified 85% of the hyperdivergent class II patients during internal validation ($p < 0.001$). The method showed 83% sensitivity and 73% specificity in external validation procedure.

Conclusions: The photographic method has proven to be a feasible, practical and reliable alternative for diagnosing the hyperdivergent class II patient in large scale epidemiological research, since a standardized protocol is followed. Caution is needed when inferring vertebral alignment from observed surface contours. Further studies must be performed in order to establish the diagnostic accuracy of the method for other skeletal patterns.

KEYWORDS: Photography; Diagnosis; Validation studies.

1 Introdução

1 Introdução

A análise de fotografias faciais tem sido realizada como auxiliar de diagnóstico na prática clínica desde os primórdios da Ortodontia[19]. Com o advento do cefalostato e a padronização da técnica radiográfica por Broadbent e Hofrath em 1931, a fotografia facial tornou-se um registro de importância secundária, utilizado apenas para fins ilustrativos[9, 15, 58], estando subordinado à cefalometria no planejamento do tratamento ortodôntico.

Diversas análises cefalométricas foram desenvolvidas ao longo dos anos, o que proporcionou a difusão dos conceitos de normalidade e anormalidade dos padrões esqueléticos faciais através de avaliações de caráter objetivo[10, 41, 53, 66, 68, 70]. Todavia, aspectos concernentes à radioproteção levantaram a possibilidade de avaliação quantitativa da morfologia craniofacial através de fotografias de perfil padronizadas[9], propiciando o aumento substancial da eficácia clínica desta ferramenta de diagnóstico[15, 27, 28, 49].

Apesar da noção de fotogrametria facial datar da época do Renascimento[51], somente a partir de meados do século XX foram encontrados os primeiros relatos na literatura acerca de mensurações antropométricas faciais realizadas através de fotografias[43, 47, 50, 67]. Posteriormente, uma gama de estudos foi publicada sobre a avaliação do perfil facial a partir de fotografias padronizadas. A grande maioria relatou diferenças entre gêneros, características raciais, avaliação de resultados do tratamento e apresentação de valores normativos para medidas faciais em populações específicas, visando utilizá-los como referência em tratamentos com finalidade estética[2, 4, 5, 9, 13-15, 33, 39, 49, 56, 57, 67].

Além de estudar as características próprias do perfil em tecido mole, autores também abordaram a importância de relacioná-lo com o padrão cefalométrico[34, 54, 55]. No entanto, poucos estudos avaliaram de forma direta o grau de correlação entre medidas cefalométricas e fotográficas, observando-se resultados conflitantes[65, 71].

Considerando o fato de que tecidos moles variam em espessura, alguns autores têm questionado se o contorno do perfil reflete com precisão as estruturas subjacentes do esqueleto[65], e se é possível determinar o padrão esquelético de um paciente a partir da análise da fotografia de perfil[24]. Zhang et al.[71] (2007) concluíram que, embora a utilização de medidas lineares e angulares para caracterizar a morfologia facial possa ser obtida de forma precisa a partir de fotografias faciais, foram encontradas apenas correlações baixas à moderadas quando comparando-as com medidas cefalométricas análogas. Por outro lado, Staudt, Kiliaridis[65] (2009) encontraram fortes correlações entre estruturas esqueléticas faciais e tecidos moles sobrejacentes em indivíduos padrão esquelético classe III.

A utilização de fotografias para o diagnóstico de alterações posturais tem sido difundida principalmente na área de fisioterapia[26, 32, 52, 69]. No entanto, ainda são raros os estudos que compararam variáveis posturais obtidas através de telerradiografias em norma lateral com aquelas provenientes de fotografias de perfil padronizadas. Estudos prévios não encontraram fortes correlações entre o alinhamento anatômico das vértebras cervicais e medidas da postura da cabeça e pescoço obtidas a partir da superfície de tecido mole[32, 52]. Por outro lado, van Niekerk et al.[69] (2008) observaram que as fotografias forneciam um indicador válido e confiável da posição da coluna subjacente.

Embora as radiografias cefalométricas constituam-se no padrão-ouro para avaliar a postura crânio-cervical [6, 29, 30, 36, 48, 60-64] e diagnosticar a morfologia esquelética craniofacial na prática clínica[10, 41, 53, 66, 68, 70], elas não são viáveis para aplicação em estudos epidemiológicos de larga escala[71]. Alternativas não invasivas foram sugeridas a fim de estabelecer um diagnóstico preciso, sem exposição dos sujeitos da pesquisa à radiação[65]. Desde métodos simplificados como a antropometria manual[11, 12], até os mais sofisticados sistemas de análise tridimensional têm sido descritos[3, 7, 16, 17, 28]. No entanto, enfatiza-se a utilização de fotografias padronizadas por se tratar de um procedimento simples, prático e de baixo custo[1, 25, 49, 65, 71]. Ou seja, uma alternativa viável para o diagnóstico preliminar em tais estudos.

A primeira parte do presente trabalho centrou-se na investigação da relação existente entre medidas obtidas a partir de telerradiografias laterais e medidas análogas provenientes de fotografias padronizadas do perfil facial, através da análise de modelos de regressão. A possibilidade de prever os valores das variáveis cefalométricas por meio de variáveis fotográficas pode ser de grande interesse na complementação da análise facial, possibilitando o diagnóstico do padrão esquelético através da utilização de fotografias padronizadas de perfil.

A segunda parte do estudo avalia a possibilidade de análise da posição da cabeça e coluna cervical através de fotografias, e exibe a precisão do método fotográfico no diagnóstico do paciente classe II hiperdivergente por meio de uma função canônica discriminante. Este tipo esquelético foi particularmente escolhido para análise por estar associado à diferentes desordens, tais como alterações posturais[6, 29, 30, 36, 40, 48, 59-64], maior prevalência de distúrbios do sono por obstrução das vias aéreas [8, 35, 37, 38, 42] e distúrbios da ATM[18, 20-23, 31, 44-46]. Entretanto, a relação de causa e efeito entre este padrão esquelético específico e possíveis condições patológicas ainda não foi elucidada, fato este que tem aumentado o interesse de pesquisadores em investigar mais profundamente estas questões.

A compreensão adequada do mecanismo que contribui para o desenvolvimento crânio-facial normal é de importância fundamental no diagnóstico e tratamento dos distúrbios morfológicos e funcionais do sistema estomatognático. Para que haja um maior entendimento a respeito da inter-relação entre morfologia craniofacial, postura crânio-cervical e o desenvolvimento de desordens funcionais, faz-se necessária a realização de estudos epidemiológicos longitudinais em larga escala, nos quais seja feito um acompanhamento, em longo prazo, de indivíduos em fase de crescimento. No entanto, a viabilidade de tal estudo está condicionada ao desenvolvimento de um método simplificado, reprodutível, que possibilite a obtenção de um diagnóstico preciso, sem expor o paciente à radiação.

2 Proposição

2 Proposição

2.1 Objetivo Geral

Descrição do método fotográfico, visando testar sua validade para o diagnóstico do padrão esquelético facial e avaliação da postura da cabeça e coluna cervical.

2.2 Objetivos específicos

1. Investigar a relação existente entre medidas cefalométricas utilizadas para diagnóstico do padrão esquelético facial e medidas craniofaciais obtidas através do método fotográfico.

2. Testar a eficácia do método fotográfico no diagnóstico do padrão esquelético classe II hiperdivergente e na avaliação da postura da cabeça e coluna cervical.

3 Capítulos

Esta dissertação de Mestrado foi redigida em capítulos correspondentes a artigos científicos para publicação em periódicos internacionais.

Capítulo 1 Photographic assessment of cephalometric measurements. Liliane de Carvalho Rosas Gomes, Karla Orfelina Carpio Horta, Luiz Gonzaga Gandini Júnior, Marcelo Gonçalves, João Roberto Gonçalves.

Artigo enviado para publicação no periódico American Journal of Orthodontics and Dentofacial Orthopedics.

Capítulo 2 Photographic assessment of hyperdivergent class II patients. Liliane de Carvalho Rosas Gomes, Karla Orfelina Carpio Horta, Luiz Gonzaga Gandini Júnior, João Roberto Gonçalves.

Artigo a ser enviado para publicação no periódico American Journal of Orthodontics and Dentofacial Orthopedics.

Considerações Éticas: O presente estudo foi previamente aprovado pelo Comitê de Ética da Faculdade de Odontologia de Araraquara sob protocolo nº 66/10, conforme certificado (Anexo 1). Os responsáveis pelos pacientes participantes desta pesquisa assinaram o termo de consentimento livre e esclarecido (Apêndice 1) e o termo de autorização para uso de imagem (Apêndices 2 e 3).

3.1 Capítulo 1

Photographic assessment of cephalometric measurements

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ABSTRACT

Introduction: Since cephalometric analysis constitutes the gold standard for diagnosing craniofacial morphology in clinical practice, the possibility of predicting cephalometric values through photographs may be relevant as a noninvasive diagnostic tool, especially for epidemiological studies.

Objectives: This study focused on the investigation of the relationship between craniofacial measurements obtained from cephalometric radiographs with analogous measurements from profile photographs.

Methods: Lateral cephalograms and standardized facial profile photographs were obtained from a sample of 123 subjects (65 girls, 58 boys, aged 7–12 years). Intraclass correlation coefficients (ICC) were calculated from repeated photographic measurements to evaluate method reliability. Analogous cephalometric and photographic measurements were compared to assess Pearson correlation coefficients. Linear regression analyses were conducted between the measurements that achieved correlation coefficients greater than $r = 0.7$.

Results: The reliability of the photographic technique was satisfactory. Most measurements showed ICC above 0.80 and highly significant correlations ($p \leq 0.001$) with cephalometric variables. Among all measurements used, A’N’B’ angle was the most effective in explaining the variability of its analogous cephalometric, mainly for female subjects ($r^2 =$

0.80). FMA' angle showed the best results for vertical assessment (r^2 = 0.65).

Conclusion: The photographic method has proven to be a reliable diagnostic tool since a standardized protocol is followed. Therefore, it may be considered a feasible and practical diagnostic alternative, particularly if there is a need for a low-cost and noninvasive method.

KEY WORDS: Photography, Diagnosis, Regression analysis

INTRODUCTION AND LITERATURE REVIEW

Photographs have long been used as an adjunct in anthropometric research and orthodontics clinical practice. However, by the advent of cephalostat and standardization of the radiographic technique, facial photography became a secondary record for several years. The emphasis was on the objective assessment of cephalometric radiographs, leaving only a subjective role for lateral photographs.[1-3]

Several cephalometric analyses were developed, which gave orthodontics a basis to expand the concept of normal and abnormal skeletal pattern. Conversely, radioprotection concerns brought to light the possibility of performing quantitative analysis through photographs, which may increase its clinical effectiveness. Actually, such quantitative analysis may serve as a powerful method to address craniofacial disorders, establish treatment planning, evaluate surgical results, orthodontic outcomes, as well as study facial growth. Thus, it may be effective either in orthodontics as in several medical fields.[1,4,5]

Although the notion of facial photogrammetry may be traced back to Renaissance,[6] it was only from the middle 20th century that the first reports emerged regarding accurate anthropometric facial measurements recorded through photographs.[7-10] Afterwards, various studies about soft-tissue evaluation on standardized two-dimensional photographs have been described. Most of them reported differences between genders, racial characteristics, treatment changes and also developed normative database to use as a guide for aesthetic treatment goals.[1,3,5,7,11-19]

Besides studying soft-tissue profile characteristics alone, it has been found consistent relationships between facial overlying tissues and skeletal structures through lateral radiographs analysis.[20-22] However, comparisons involving cephalometric and photographic measurements have been seldom performed, and conflicting results found.[23,24]

Zhang et al.[23] noticed that although both linear and angular craniofacial measurements could be reliably determined from facial photographs, only low to moderate correlations with analogous cephalometric measurements were found. Contrariwise, Staudt and Kiliaridis [24] found strong correlations between soft-tissue facial characteristics and skeletal variables.

Although normative data for facial analysis have been described, cephalometry still constitutes the current gold standard for diagnosing skeletal craniofacial morphology in clinical practice. Therefore, the possibility of predicting cephalometric findings through photographs may be relevant to supplement facial analysis, especially if there is a need for a low-cost and noninvasive diagnostic method. This study focused on the investigation of the relationship between craniofacial measurements obtained from cephalometric radiographs with analogous measurements from standardized facial profile photographs by means of regression prediction models.

MATERIALS AND METHODS

Study population

Lateral cephalograms and standardized profile photographs were obtained from 123 subjects, 65 girls and 58 boys, aged between 7 and 12 years (mean 8.9 yrs, SD 1.4). The inclusion criteria were (1) no previous orthodontic or surgical treatment, (2) all six maxillary anterior teeth present, (3) no craniofacial trauma, (4) no congenital anomalies and (5) no neurological disturbances. The sample comprised children admitted for the treatment of various malocclusions at Araraquara Dental School, UNESP and private academic institutions. Thus, lateral radiographs were 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.

Photographic procedure

Standardized right profile photographs were taken in natural head position (NHP), maximum intercuspation and lips at rest. Previously, glasses were removed and hairs piled high on the head, ensuring that the patient’s forehead, neck, and ears were clearly visible. Adhesive dots were placed on anatomical landmarks identified by palpation (Fig. 1). Me’ point was identified with an adhesive styrofoam bead to allow better visibility by the camera. To obtain NHP, a 75 X 30 cm mirror was hung on a tripod which allows vertical adjustments according to subject’s height. Patients were asked to keep feet slightly apart, arms relaxed and stand a step behind a line drawn 120 cm away from the mirror. They were instructed to tilt their head up and down with decreasing amplitude until they felt relaxed, and take a step forward, keep looking straight ahead into the reflection of their eyes in the mirror, to achieve the “orthoposition”.[25,26] A protractor was placed on nose tip and soft-tissue Pogonion, and a plumb line recorded the NHP angle (Fig. 2).[27]

The same digital camera (Canon EOS Digital Rebel XT, Tokyo, Japan) mounted with the same lens (Canon EF 100mm f/2.8 USM Macro Lens, Tokyo, Japan) and flash (Canon Macro Ring Lite MR-14EX flash, Tokyo, Japan) was used for all photographic records. It was secured on a tripod for stabilization and adjustment according to the subject's height. The 100-mm macro lens was chosen to avoid facial deformations and maintain natural proportions. The camera was used in its manual position to achieve maximum image quality given the local lighting condition. A 15 cm vertical scale was adapted in a plumb line, which indicated the true vertical (VER). The scale was positioned in the midsagittal plane in order to allow later measurements at life size (1:1). The photograph studio was designed according to figure 3.

Radiographic method

Digital lateral skull radiographs were taken with a Kodak 8000C (Kodak Dental Systems, Carestream Health, Atlanta, USA). This radiographic system uses a CCD sensor chip as an image receptor. The exposure parameters for the digital cephalographs were 78 kV, 10 mA, and 0.6 seconds. Cephalometric radiographs were taken in NHP (mirror position), maximum intercuspation and lips at rest. A chain with a 200g weight hung at its end was suspended in front of the patient, in the midsagittal plane, to register the VER. The chain was also used as a scale, in order to allow later measurements at life size (1:1) (Fig. 4). Given the possibility of cephalostat interference during NHP achievement, a protractor, modified with a plumb line,[27] was placed on nose tip and soft-tissue Pogonion to check if the same position achieved during photographic record had been also obtained during radiographic record.

Computerized assessment

Both digital photographic and radiographic records were analyzed with Radiocef® 2.0 (Radio Memory Ltda., Belo Horizonte, MG, Brazil) software for Windows. A specific analysis was previously customized using the landmarks defined for the purpose of this study. Table I shows detailed descriptions of the landmarks and reference planes used in this investigation. Traditional cephalometric angular and linear measurements (Fig. 5) and analogous photographic ones were used for sagittal and vertical assessment (Figs. 6, 7). 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 analysis of facial morphology through radiographs and photographs were performed by the same operator in a blind design.

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, the same rater replaced the adhesive dots on pre-established anatomical landmarks. Then, another picture was taken. Reproducibility analysis was 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 adhesive dots prior to taking the picture.

Statistical analysis

Data were subjected to statistical analysis using Statistical Package for the Social Sciences (SPSS), version 16.0 (SPSS Inc Chicago, IL, USA). Descriptive statistics were given for each photographic and cephalometric variable. Sexual dimorphism was evaluated by independent sample t-test. Intraclass correlation coefficients (ICC) were estimated from repeated photographic measurements to evaluate the repeatability and reproducibility of the method. Cephalometric measurements were compared with analogous photographic to assess Pearson correlation coefficients. Linear regression analyses were made between cephalometric (dependent variable to be estimated) and photographic (independent variable) measurements that achieved correlation coefficients greater than r = 0.7. Levels of $p < 0.05$ were considered statistically significant.

RESULTS

Photographic technique repeatability and reproducibility, regarding sagittal diagnostic variables, were excellent. All measurements showed an intraclass correlation coefficients (ICC) greater than 0.90. Considering variables used for assessing vertical diagnosis, the reliability of the photographic technique was also satisfactory, with most of the measurements showing ICC above 0.80 (Table II).

Means, standard deviations, ranges and gender differences for all cephalometric and photographic measurements are summarized in tables III and IV. In general, not significant gender differences were found for cephalometric measurements. Only the OPA was significantly greater in female subjects ($p \leq 0.05$), which was not observed in photographic assessment. Significant differences were found for four photographic variables: A'N'B', LAFH', PFH' and PFH'/AFH' ($p \leq 0.05$ to $p \leq 0.01$).

It was found highly significant correlations ($p \leq 0.001$) for most sagittal and vertical diagnostic variables. Coefficients ranged from weak to strong. 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 ones were obtained for LPFH versus PFH' (r = 0.49) and PFH/AFH versus PFH'/AFH' (r = 0.47) (Table V).

Linear regression results are listed in table VI. Figures 8 and 9 illustrate such outcomes through scatterplots. Overall, the photographic variable which best explained the variability of its analogous cephalometric measurement was the A'N'B' angle (r^2= 0.68). Considering only female subjects, the A'N'B' presented an even higher coefficient of determination (r^2= 0.80). Among the photographic variables used for vertical diagnosis, FMA' showed the best results (r^2= 0.65).

DISCUSSION

Cephalometric analysis constitutes the current gold standard for diagnosing skeletal craniofacial morphology in orthodontics clinical practice. However, the photographic assessment has seemed to be a great diagnostic tool for epidemiological studies, since it provides cost-effectiveness and do not expose the patient to potentially harmful radiation.[1] Through repeatability test, it was found that both linear and angular measurements useful for characterizing facial morphology can be reliable measured from facial photographs, which corroborates previous studies.[3-5,12,18,23,24,28,29] This finding suggests that photography might be a feasible and practical alternative when radiography is considered too invasive or logistically impractical.[18,23]

Direct anthropometry may represent another practical alternative for craniofacial morphology diagnosis, however, standardized photographic technique has shown several advantages over it. Since the subjects do not move, it is easier to measure; there is no skin pressure related errors; and the period of interaction with the subject is potentially shorter. Moreover, measurements can be performed repeatedly and data stored permanently, which makes feasible longitudinal follow-up studies.[4,5]

Conversely, photographic technique incorporates some shortcomes such as the distortion by lens-subject distance [4,12] that causes objects near the camera appear larger than those farther from it. However, this factor is only critical when attempting to compare structures located in different planes of space. Since most landmarks obtained from lateral photographs in the current study are at the midline, this issue should minimally affect the measurements.[12] In addition, it was most commonly used angular variables, which partially overcome the problem of magnification.

Another source of error concerns head posture, which must be the same during radiographic and photographic recording protocol. Even a slight deviation of the natural head position can greatly affect landmarks location and modify measurements results.[24] Furthermore, jaw opening, or lips straining by mentalis muscle constriction may increase error.[2,24]

A standardized photography protocol also includes accurate establishment of landmarks. In this study, it was set out nine landmarks of which four were obtained by palpation. Previous studies reported difficulty in marking Go' and Me' when cheeks were fat or plump [4] and the soft-tissue under the chin was redundant [12]. In spite of only 10% of the current sample had been comprised of fat or chubby patients, it was observed greater difficulty in positioning the adhesive dots in such cases.

Considering that most photographic measurements were performed based on anatomical points achieved by palpation, reproducibility test was conducted to find the reliability in positioning the stickers, without the interference of other source of error. Hence, only one operator performed computerized analysis and picture taking. Results of our investigation showed that method reproducibility was also satisfactory.

Although different skeletal facial patterns composed the current sample, in general, no significant gender differences were found for cephalometric measurements, which confirms the similar distribution into male and female subgroups. However, differences were found for A'N'B', LAFH', PFH' and PFH'/AFH' photographic variables, which were significantly higher in males ($p \leq 0.05$ to $p \leq 0.01$). Previous authors have reported sexual dimorphism in most parameters of labial, nasal, and chin areas when evaluating photographs. Male faces showed, on average, greater heights and lengths as well as greater prominences of these areas.[1,15]

Fernandez-Riveiro et al. [15] noticed that the Sn point was more prominent in males, which may explain in part the A'N'B' angle dimorphism. Studies have also reported significantly larger values for LAFH’ and PFH’ in males, which agreed with our findings.[1,15,28,30] However, LAFH’/AFH’ and PFH’/LAFH’ ratio showed no significant gender differences in our study. Therefore, although male subjects showed greater absolute measurements, the values maintain similar proportions for both male and female subjects.

The age group in the current study (7-12 yrs) was selected because it encompasses a period which the interrelationship between hard and soft-tissue shapes should be particularly close, without the added variability of aging effects in adults.[2] It was found highly significant correlations ($p \leq 0.001$) between analogous cephalometric and photographic measurements for most sagittal and vertical diagnostic variables. However, Pearson correlation coefficients ranged from weak to strong ($0.39 \leq r \leq 0.89$). It means that although there was a significant tendency for analogous photographic and cephalometric variables to vary together, this tendency was strong for some measurements and weak for others.

In a previous study, Zhang et al. [23] reported only low to moderate correlations ($0.36 \leq r \leq 0.64$). Analogous photographic and cephalometric LAFH showed the highest one observed ($r = 0.64$). When comparing FMA’ with the cephalometric SN.GoMe, the authors found a weak correlation coefficient ($r = 0.42$).[23] Contrariwise, by correlating cephalometric and photographic FMA analogous angles in Bittner and Pancherz’s study (r =

0.93),[31] and in the current paper (r = 0.81), it was observed strong correlations. Such difference might be related to the inclination of intracranial SN line, which has shown individual variations.[32,33]

Staudt and Kiliaridis [24] observed that several soft-tissue measurements gave a reliable description of the underlying sagittal jaw relationship. A correlation coefficient of r = 0.80 was reported when comparing analogous photographic and cephalometric ANB angles. Our results largely support these findings. Other authors found moderate correlations regarding such variables (r = 0.63).[31]

Investigators evaluated the relationship between three-dimensional soft-tissue measurements and well-established two-dimensional cephalometric variables which analyze anteroposterior discrepancy. They noticed that the soft-tissue Wits was significantly correlated to the conventional Wits appraisal (r = 0.77),[34] which corroborates our results through photographic analysis (r = 0.73). It was also assessed Camper Wits to supply an entirely external method for quantitative evaluation of jaw discrepancies. However, only moderate relationship was found with the conventional cephalometric Wits appraisal (r = 0.53). Our result regarding the Frankfurt plane (A'-B'perp) presented a slightly greater value (r = 0.61).

Linear regression analysis showed that the photographic variable which best explained the variability of its analogous cephalometric measurement in the current study was the A'N'B' angle (r^2= 0.68). It means that at least 68% of the variance of the cephalometric assessment can be explained by such photographic measurement given the total sample. This finding largely supports a previous report which found a coefficient of determination of r^2= 0.63 between analogous soft-tissue and skeletal ANB angles.[24] In the present sample, A'N'B' showed an even higher coefficient of determination (r^2= 0.80) among female subjects, which means that the soft-tissue thickness variability exerts less influence in these patients. Regarding vertical assessment, FMA' showed the best results (r^2= 0.65).

This paper provided regression models that may predict the cephalometric variable by means of analogous photographic ones with a limited error of the estimate and a satisfactory predictive power. Further studies must be performed in order to establish the diagnostic accuracy of such models.

CONCLUSIONS

- Highly significant correlations between analogous photographic and cephalometric measurements were found for most sagittal and vertical diagnostic variables.
- A'N'B' and FMA' angles were the photographic variables that best explained the variability of its analogous cephalometric measurement.

- The photographic method showed to be a reliable, low-cost and noninvasive diagnostic alternative since a standardized protocol is followed. Further studies are needed in order to test the diagnostic accuracy of the predictive models obtained.

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FIGURES

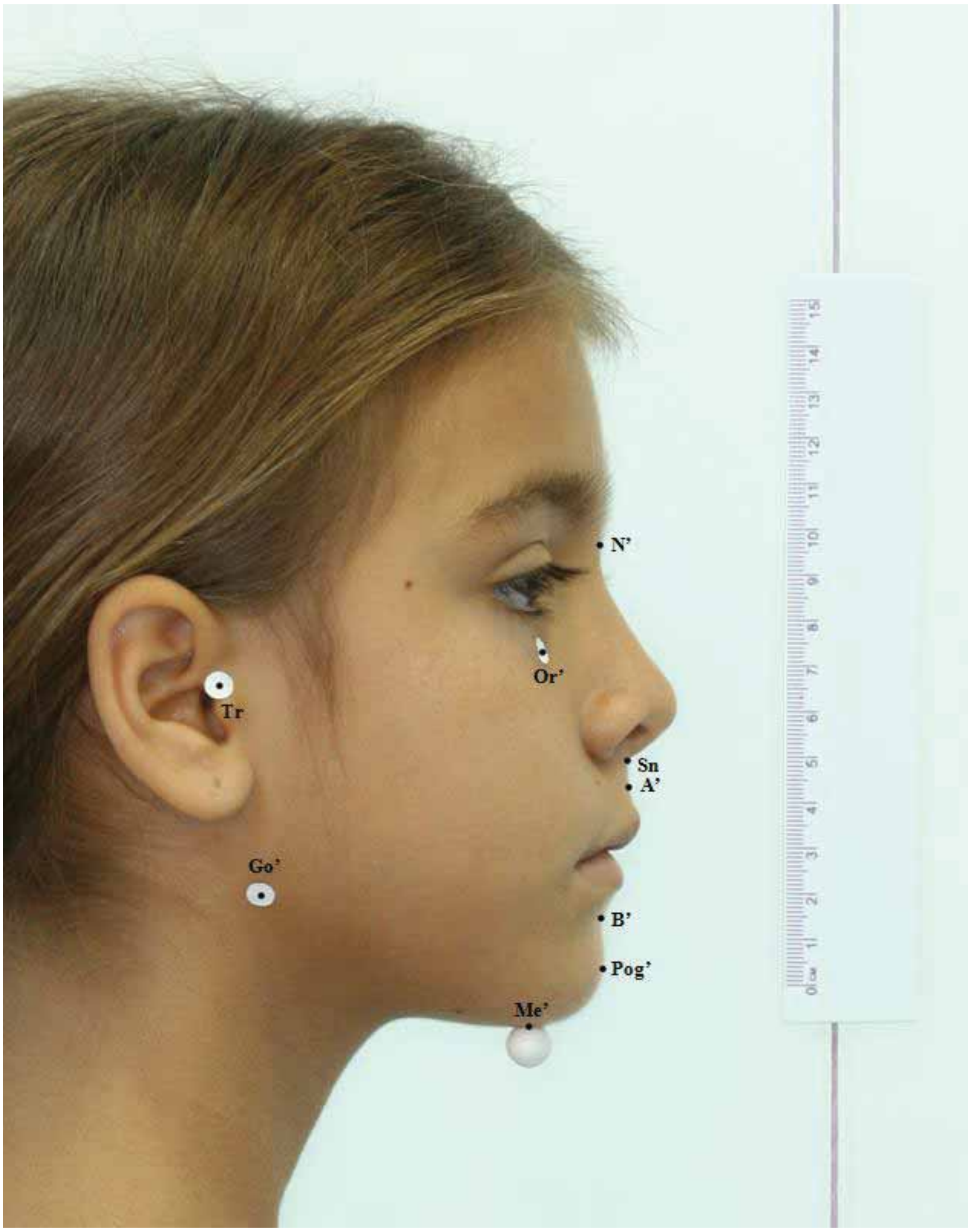

Figure 1. Photographic landmarks. N', Soft-tissue Nasion; Tr, Tragion; Or', Soft-tissue Orbitale; A', Soft-tissue Subspinale; B', Soft-tissue Supramentale; Go', Soft-tissue Gonion; Pog', Soft-tissue Pogonion; Me', Soft-tissue Menton; Sn, Subnasale. Adhesive dots were placed on Tr, Or' and Go'. Me' point was marked with an adhesive styrofoam bead to allow better visibility by the camera

Figure 2. Modified protractor on nose tip and soft-tissue Pogonion to assess NHP

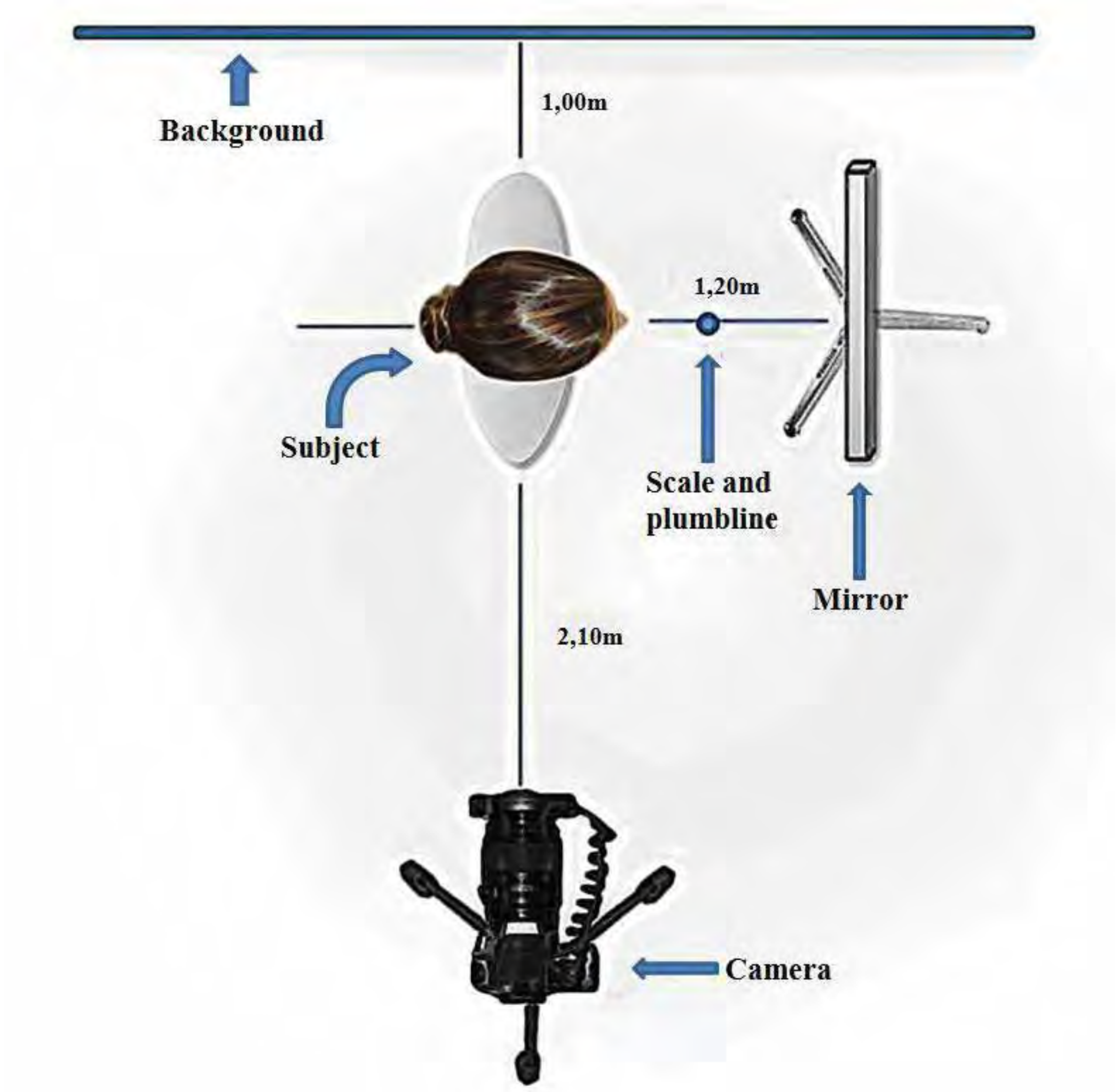

Figure 3. Photographic setup

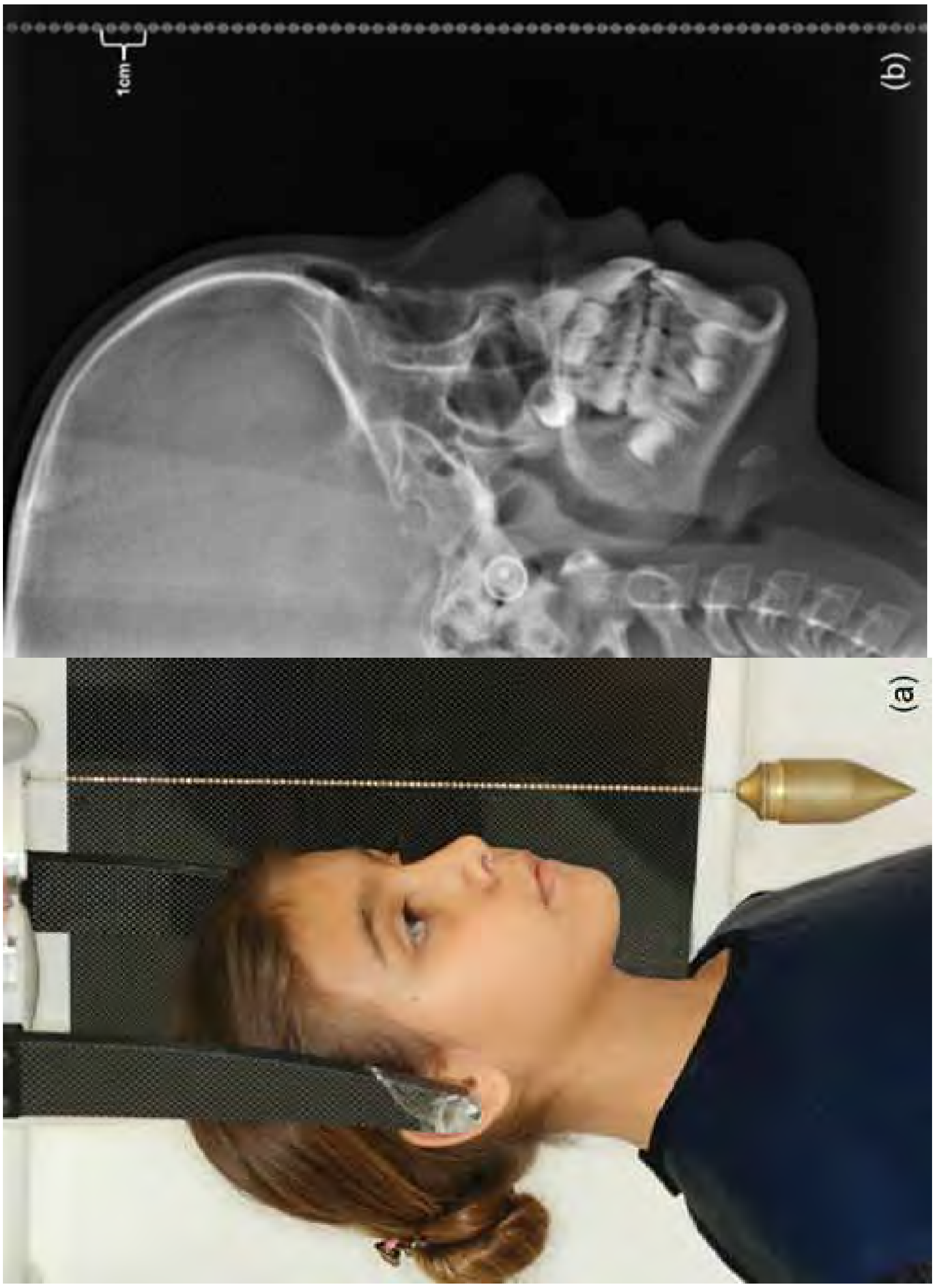

Figure 4. (a) Subject placed in the cephalostat; (b) Digital radiographic record

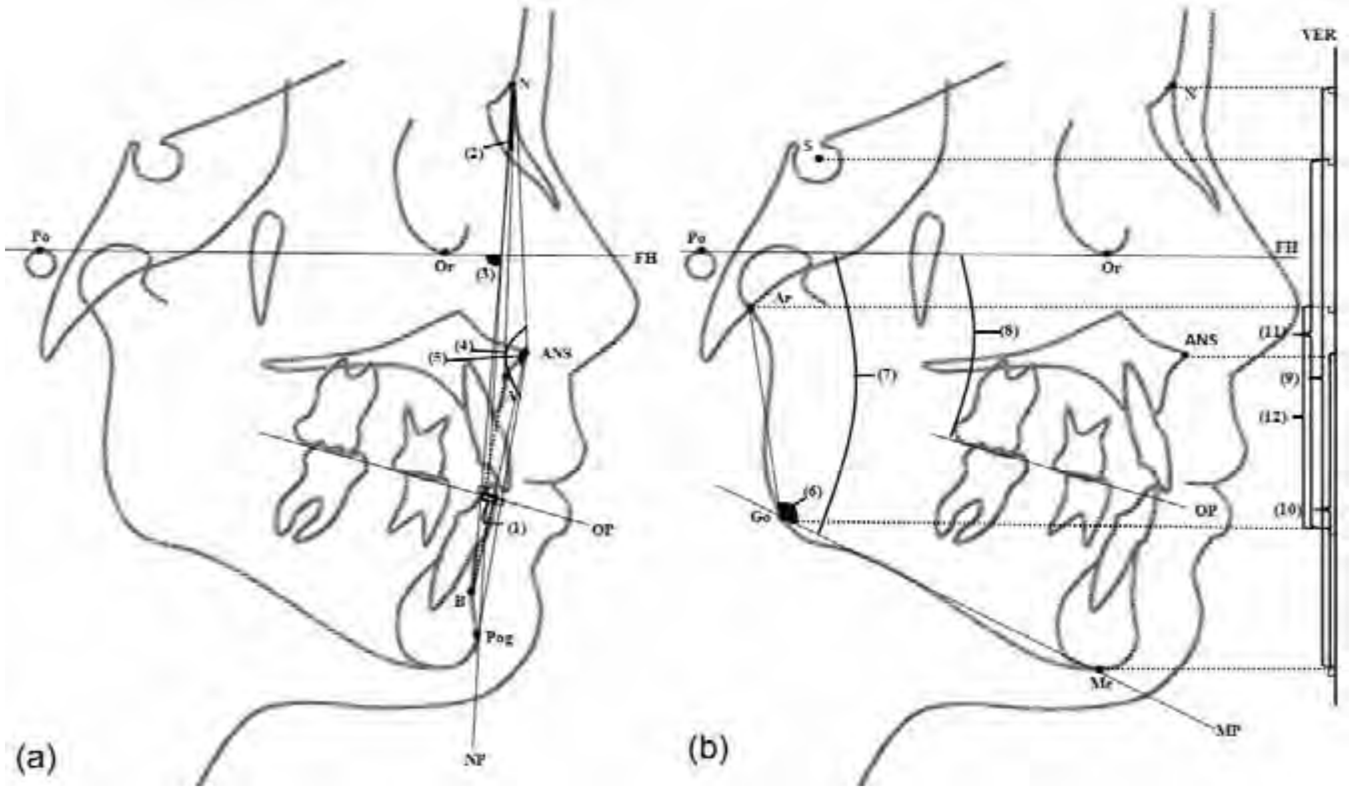

Figure 5. Cephalometric measurements. (a) Sagittal assessment: (1) Wits, maxillomandibular linear discrepancy; (2) ANB, maxillomandibular angular discrepancy; (3) FNP, facial angle; (4) N.ANS.Pog, (5) N.ANS.B, angles of facial convexity. (b) Vertical assessment: (6) Ar.Go.Me, gonial angle; (7) FMA, Frankfurt 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

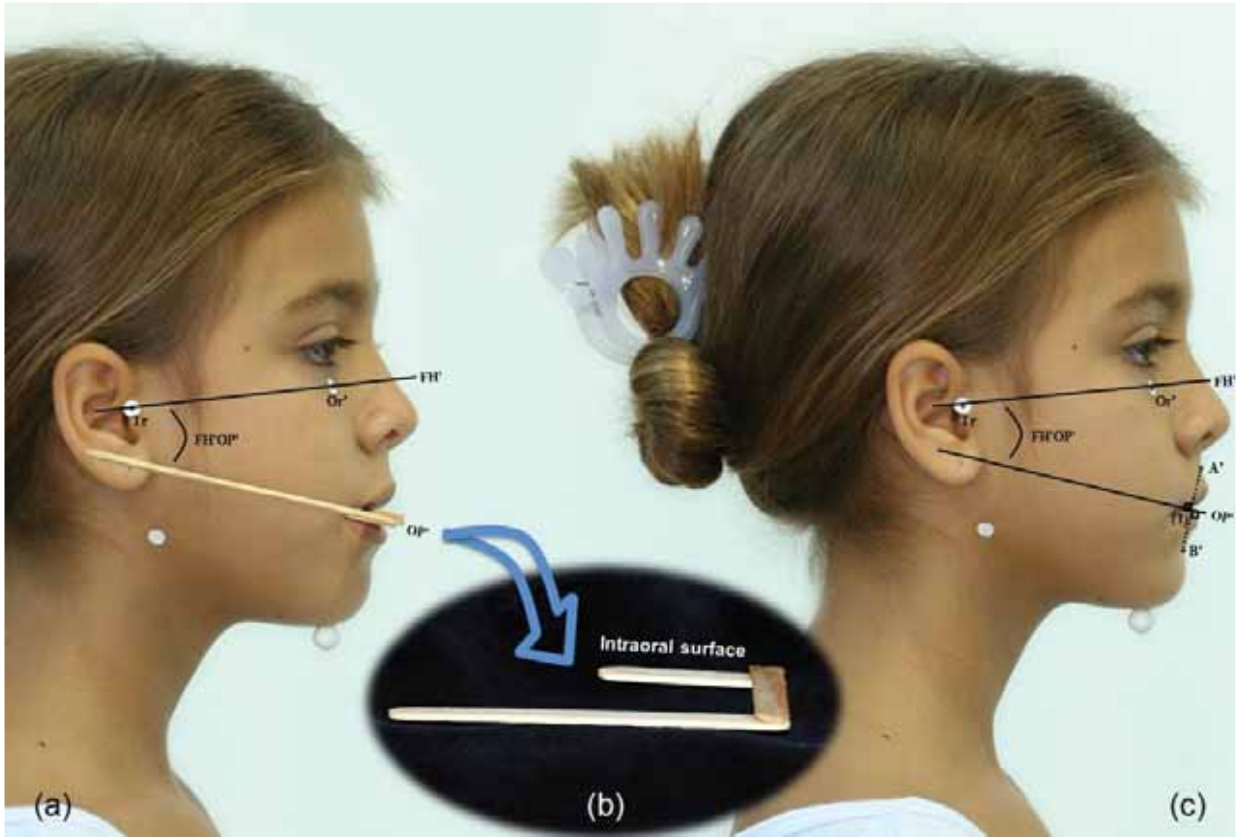

Figure 6. Photographic measurements. Sagittal assessment: (1) Wits', soft-tissue maxillomandibular linear discrepancy. (a) patient occluding a wooden spatulas device, (b) schematic representation of the device, (c) distance A'-B' obtained after the transfer of FH'OP' angle to the photography held in maximum intercuspation

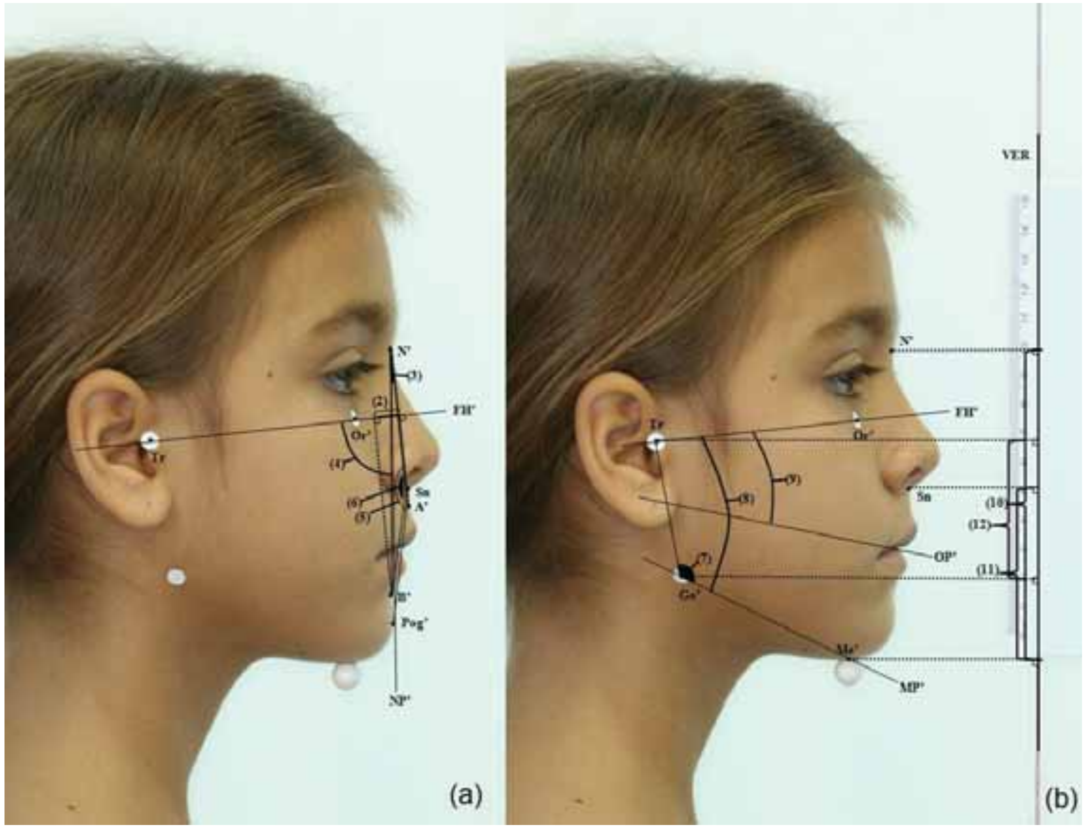

Figure 7. Photographic measurements continuation. (a) Sagittal assessment: (2) A'-B'perp, soft-tissue maxillomandibular linear discrepancy; (3) A'N'B', soft-tissue maxillomandibular angular discrepancy; (4) FNP', soft-tissue facial angle; (5) N'.Sn.Pog', (6) N'.Sn.B', soft-tissue angles of facial convexity. (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

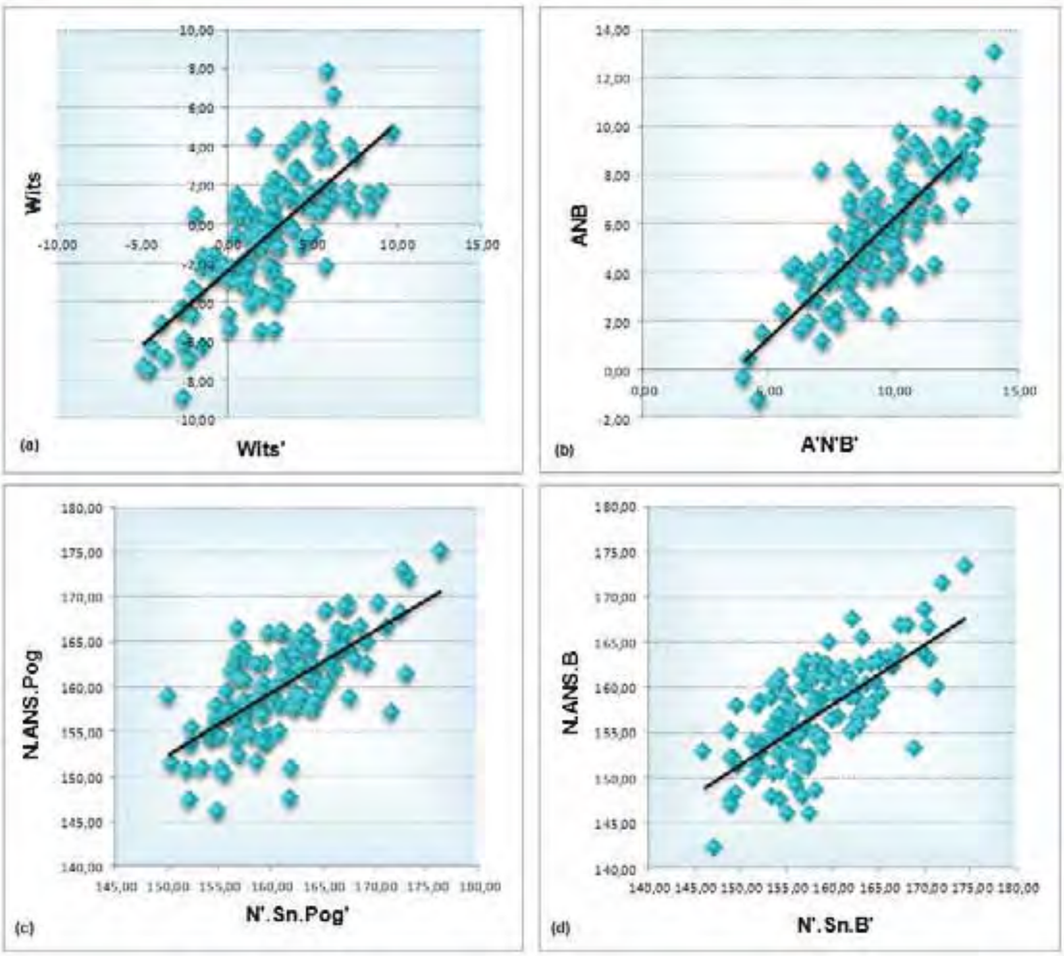

Figure 8. Scatterplots illustrating linear regression results between cephalometric and photographic measurements used for sagittal assessment (n=123). (a) Wits vs. Wits', (b) ANB vs. A'N'B', (c) N.ANS.Pog vs. N'.Sn.Pog', (d) N.ANS.B vs. N'.Sn.B'

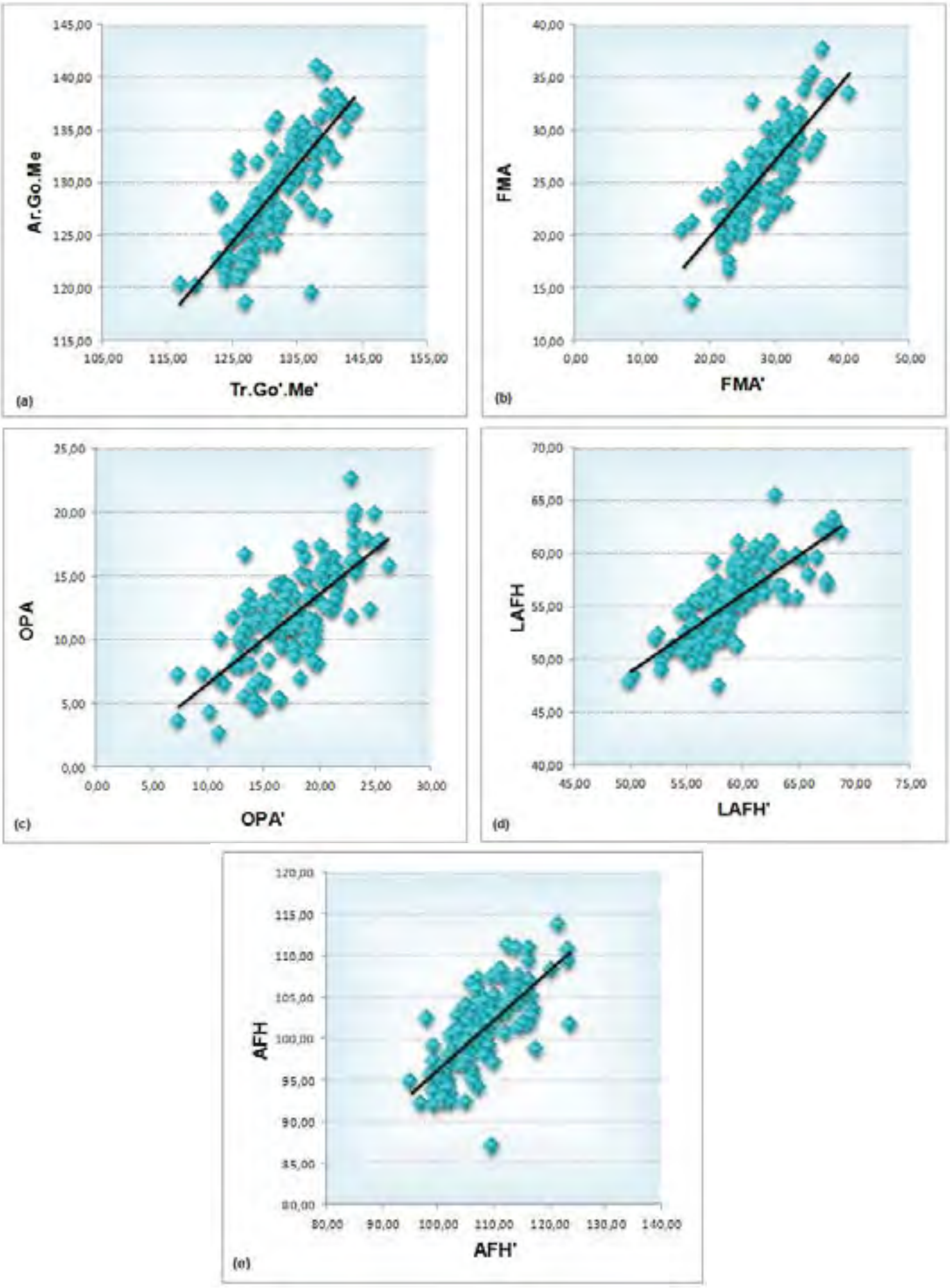

Figure 9. Scatterplots illustrating linear regression results between cephalometric and photographic measurements used for vertical assessment (n=123). (a) Ar.Go.Me vs. Tr.Go'.Me', (b) FMA vs. FMA', (c) OPA vs. OPA', (d) LAFH vs. LAFH', (e) AFH vs. AFH'

TABLES

Table I. Reference landmarks and planes used for the purpose of this study

Anatomical landmarks and planes	Symbol	Definition
Photographic parameters:		
Soft-tissue Nasion	N’	Point in the middle line located at the nasal root
Tragion	Tr	Posterior and superior point of the auricular tragus
Soft-tissue Orbitale	Or’	Lowest point in bony orbit below right eye obtained by palpation
Soft-tissue Subspinale	A’	Deepest point on anterior concavity of the upper lip
Soft-tissue Supramentale	B’	Deepest point of the inferior sublabial concavity
Soft-tissue Gonion	Go’	The most posterior and inferior point at the angle of the mandible obtained by palpation
Soft-tissue Pogonion	Pog’	The most anteriorly located point on the chin
Soft-tissue Menton	Me’	The most inferior point of the chin obtained by palpation
Subnasale	Sn	Point on the bottom of the cutaneous part of the nasal septum
Soft-tissue Frankfurt horizontal plane	FH’	Horizontal plane running through Tragion and soft-tissue Orbitale
Soft-tissue mandibular plane	MP’	Line extending between soft-tissue Gonion and Menton
Soft-tissue occlusal plane	OP’	Defined by the occlusion of a wooden spatula device
Soft-tissue facial plane	NP’	Line extending between soft-tissue Nasion and Pogonion
Cephalometric parameters:		
Nasion	N	The most anterior point of the frontonasal suture
Articulare	Ar	The intersection between the external contour of the cranial base and the dorsal contour of the condylar head or neck
Porion	Po	The midpoint on the upper edge of the externals acoustic meatus
Orbitale	Or	The lowest point on the lower margin of the bony orbit (midpoint between right and left images)
Subspinale	A	The most posterior point on the anterior contour of the upper alveolar process
Supramentale	B	The most posterior point on the anterior contour of the lower alveolar process
Gonion	Go	The point on which the jaw angle is the most interiorly, posteriorly, and outwardly directed
Pogonion	Pog	The most anteriorly located point on the mandibular symphysis
Menton	Me	The most inferior point in the contour of the mandibular symphysis
Anterior Nasal Spine	ANS	Tip of the anterior nasal spine seen on the lateral radiographs

Sella turcica	S	The midpoint of Sella turcica
Frankfurt horizontal plane	FH	Horizontal plane running through Porion and Orbitale
Mandibular plane	MP	Line extending between Gonion and Menton
Occlusal plane	OP	Line that joins the midpoint of the overlap of the mesio-buccal cusp of the first molar and the buccal cusp of the first premolar (as defined by Jacobson) [60]
Facial plane	NP	Line extending between Nasion and Pogonion

Table II. Repeatability and reproducibility of photographic method assessed by intraclass correlation coefficients (ICC)

Photographic Measurement	Repeatability (n = 27)			Reproducibility (n = 20)		
	ICC	Lower bound	Upper bound	ICC	Lower bound	Upper bound
Sagittal Assessment:						
Wits'	0.904	0.803	0.955	0.910	0.790	0.963
A'-B'perp	0.945	0.884	0.974	0.934	0.844	0.973
A'N'B'	0.964	0.923	0.983	0.954	0.891	0.982
FNP'	0.903	0.801	0.954	0.899	0.768	0.959
N'.Sn.Pog'	0.980	0.958	0.991	0.970	0.927	0.988
N'.Sn.B'	0.981	0.959	0.991	0.955	0.893	0.982
Vertical Assessment:						
Tr.Go'.Me'	0.946	0.886	0.975	0.814	0.594	0.921
FMA'	0.942	0.879	0.973	0.850	0.665	0.937
OPA'	0.813	0.634	0.910	0.855	0.675	0.940
LAFH' (Sn-Me')	0.855	0.710	0.931	0.909	0.789	0.963
AFH' (N'-Me')	0.838	0.678	0.922	0.878	0.723	0.950
PFH' (Tr-Go')	0.754	0.533	0.879	0.731	0.443	0.883
LAFH'/ AFH'	0.883	0.763	0.945	0.941	0.860	0.976
PFH'/ AFH'	0.796	0.604	0.901	0.782	0.535	0.907
PFH'/ LAFH'	0.832	0.668	0.919	0.826	0.618	0.927

Table III. Descriptive statistics for cephalometric measurements and differences between the groups by independent sample t-test

	All subjects (n = 123)				Male (n = 58)				Female (n = 65)				Gender differences	
Measurements	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**SD**	**Min**	**Max**	**Mean**	**Sig.**
Sagittal Assessment:														
Wits	-0.68	3.14	-8.90	7.83	-0.12	2.65	-7.32	4.55	-1.17	3.46	-8.90	7.83	1.06	NS
ANB	5.73	2.54	-1.26	13.08	5.90	2.21	0.44	11.76	5.59	2.81	-1.26	13.08	0.31	NS
FNP	87.67	2.53	81.77	95.15	87.85	2.35	81.77	93.54	87.52	2.68	82.73	95.15	0.33	NS
N.ANS.Pog	160.14	5.41	146.09	175.21	160.43	4.29	146.09	172.09	159.88	6.26	147.46	175.21	0.55	NS
N'.ANS.B	157.00	5.55	142.15	173.40	157.07	4.38	145.98	168.48	156.94	6.45	142.15	173.40	0.13	NS
Vertical Assessment:														
ArGoMe	129.52	5.05	118.61	141.03	129.42	4.92	120.27	138.28	129.60	5.20	118.61	141.03	-0.18	NS
FMA	25.99	4.12	13.69	37.68	25.34	3.75	17.54	35.37	26.57	4.37	13.69	37.68	-1.23	NS
OPA	11.95	3.82	2.58	22.61	11.21	3.41	4.24	19.65	12.61	4.07	2.58	22.61	-1.40	*
LAFH (ANS-Me)	55.53	3.59	47.47	65.48	56.04	3.33	47.47	63.36	55.08	3.77	47.89	65.48	0.95	NS
AFH (N-Me)	101.18	4.97	87.00	113.67	102.05	4.85	87.00	111.30	100.40	4.98	92.08	113.67	1.65	NS
PFH (S-Go)	63.00	3.97	52.46	73.82	63.73	4.13	52.46	73.82	62.35	3.73	55.36	70.84	1.38	NS
LPFH (Ar-Go)	36.29	3.12	29.70	43.75	36.75	2.91	30.39	43.75	35.88	3.26	29.70	43.59	0.88	NS
LAFH/ AFH	0.55	0.02	0.51	0.60	0.55	0.02	0.51	0.60	0.55	0.02	0.51	0.60	0.00	NS
PFH/ AFH	0.62	0.03	0.54	0.70	0.62	0.03	0.54	0.69	0.62	0.03	0.54	0.70	0.00	NS
LPFH/ LAFH	0.65	0.06	0.51	0.82	0.66	0.06	0.51	0.82	0.65	0.06	0.52	0.77	0.00	NS

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

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

	All subjects (n = 123)				Male (n = 58)				Female (n = 65)				Gender differences	
Measurements	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	Sig.
Sagittal Assessment:														
Wits'	2.30	3.02	-4.95	9.71	2.82	3.13	-4.95	9.04	1.84	2.86	-4.55	9.71	0.98	NS
A'-B'perp	11.85	3.17	3.46	18.70	12.23	2.90	5.81	18.50	11.52	3.39	3.46	18.70	0.72	NS
A'N'B'	9.40	2.12	3.97	13.98	9.81	2.02	4.18	13.33	9.03	2.14	3.97	13.98	0.78	*
FNP'	84.93	3.24	76.67	94.41	85.14	2.86	77.59	92.13	84.75	3.55	76.67	94.41	0.39	NS
N'.Sn.Pog'	161.17	5.34	150.12	176.38	160.86	5.15	150.12	173.35	161.44	5.52	150.48	176.38	-0.58	NS
N'.Sn.B'	158.16	5.78	146.03	174.30	157.69	5.48	146.03	171.40	158.58	6.05	147.03	174.30	-0.88	NS
Vertical Assessment:														
Tr.Go'.Me'	131.99	5.51	116.89	143.98	131.53	5.86	116.89	143.98	132.40	5.19	123.18	142.27	-0.87	NS
FMA'	28.08	4.46	15.91	40.87	27.60	4.72	15.91	40.87	28.50	4.22	17.40	37.43	-0.90	NS
OPA'	17.61	3.93	7.22	26.25	17.13	3.76	7.22	25.18	18.04	4.05	7.27	26.25	-0.91	NS
LAFH' (Sn-Me')	59.03	3.83	49.80	68.84	59.81	3.62	54.55	68.84	58.34	3.90	49.80	68.17	1.48	*
AFH' (N'-Me')	108.02	5.84	94.93	123.79	108.80	5.37	99.28	123.08	107.32	6.18	94.93	123.79	1.48	NS
PFH' (Tr-Go')	50.35	4.63	37.99	61.74	51.58	4.25	43.49	61.32	49.24	4.71	37.99	61.74	2.34	**
LAFH'/ AFH'	0.55	0.02	0.50	0.60	0.55	0.02	0.51	0.60	0.54	0.02	0.50	0.59	0.01	NS
PFH'/ AFH'	0.47	0.04	0.38	0.56	0.47	0.04	0.40	0.56	0.46	0.04	0.38	0.55	0.01	*
PFH'/ LAFH'	0.85	0.08	0.67	1.07	0.86	0.08	0.71	1.02	0.85	0.08	0.67	1.07	0.02	NS

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

Table V. Correlation coefficients between cephalometric and photographic measurements

Measurement parameters		All subjects (n = 123)		Male (n = 58)		Female (n = 65)	
Cephalometric	Photographic	Correlation	Sig.	Correlation	Sig.	Correlation	Sig.
Sagittal Assessment:							
Wits	Wits’	0.73	***	0.67	***	0.78	***
Wits	A’-B’perp	0.61	***	0.51	***	0.65	***
ANB	A’N’B' [a]	0.82	***	0.74	***	0.89	***
FNP	FNP'	0.61	***	0.55	***	0.65	***
N.ANS.Pog	N'.Sn.Pog'	0.68	***	0.56	***	0.77	***
N.ANS.B	N'.Sn.B'	0.69	***	0.55	***	0.78	***
Vertical Assessment:							
ArGoMe	Tr.Go'.Me'	0.79	***	0.82	***	0.78	***
FMA	FMA'	0.81	***	0.81	***	0.81	***
OPA [a]	OPA'	0.72	***	0.66	***	0.75	***
LAFH (ANS-Me)	LAFH' (Sn-Me') [a]	0.78	***	0.75	***	0.79	***
AFH (N-Me)	AFH' (N'-Me')	0.70	***	0.63	***	0.75	***
LPFH (Ar-Go)	PFH' (Tr-Go') [a]	0.49	***	0.51	***	0.45	***
PFH (S-Go)	PFH' (Tr-Go') [a]	0.53	***	0.48	***	0.53	***
LAFH/ AFH	LAFH'/ AFH’	0.63	***	0.61	***	0.66	***
PFH/ AFH	PFH'/ AFH'	0.47	***	0.39	**	0.54	***
LPFH/ LAFH	PFH'/ LAFH'	0.48	***	0.48	***	0.48	***

** $p \le 0.01$; *** $p \le 0.001$

[a] Variables that presented sexual dimorphism

Table VI. Linear regression analysis between cephalometric and photographic measurements (n=123)

Linear predictor function (y = a + bx)							Coefficient of determination
Cephalometric variables (y)	Photographic variables (x)		Intercept coefficient (a)	Slope coefficient (b)	Sig.	Std. Error of the Estimate	(r^2)
Sagittal Assessment:							
Wits	**Wits'**	T	-2.432	0.762	***	2.15	0.54
ANB	**A'N'B'**	T	-3.555	0.988	***	1.45	0.68
		M	-2.030	0.808	***	1.50	0.54
		F	-4.963	1.168	***	1.28	0.80
N.ANS.Pog	**N'.Sn.Pog'**	T	48.385	0.693	***	3.96	0.47
N.ANS.B	**N'.Sn.B'**	T	52.371	0.662	***	4.03	0.48
Vertical Assessment:							
Ar.Go.Me	**Tr.Go'.Me'**	T	33.416	0.728	***	3.08	0.63
FMA	**FMA'**	T	5.086	0.745	***	2.45	0.65
OPA	**OPA'**	T	-0.313	0.696	***	2.68	0.51
LAFH (ANS-Me)	**LAFH' (Sn-Me')**	T	12.598	0.727	***	2.27	0.60
		M	14.823	0.689	***	2.22	0.56
		F	10.638	0.762	***	2.34	0.62
AFH (N-Me)	**AFH' (N'-Me')**	T	36.733	0.597	***	3.56	0.49

*** $p \leq 0.001$

T-total sample (n=123), M- male (n=58), F-female (n=65). Values for M and F groups were only shown for the variables which presented sexual dimorphism regarding photographic variables.

3.2 Capítulo 2

Photographic assessment of hyperdivergent class II patients

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ABSTRACT

Introduction: Temporomandibular disorders (TMD), sleep disturbances and postural changes constitute some of the problems that have been associated with hyperdivergent class II patients. Simplified procedures for diagnosing these individuals in epidemiological studies have not been developed so far.

Objectives: The purpose of this study was to test the validity of the photographic method in diagnosing the hyperdivergent class II patient.

Methods: Lateral cephalograms and standardized profile photographs were obtained from a sample of 123 subjects (65 girls, 58 boys, aged 7–12 years) assigned into two groups. 51 patients comprised the hyperdivergent class II group (ANB>4.5º and SN.GoMe>36º) and the other 72 composed a second group. Cephalometric measurements were compared with analogous photographic in order to assess Pearson correlation coefficients. Discriminant analysis described a mathematical model to better diagnose the hyperdivergent class II patient through photographs. Intraclass correlation coefficients (ICC) were calculated from repeated photographic measurements.

Results: Method reliability was satisfactory. Most measurements showed ICC above 0.80. It was found highly significant correlations ($p \leq 0.001$) for almost all analogous diagnostic variables. No significant correlations were found for some postural variables. A canonical discriminant function composed of two photographic variables (A'N'B', FMA') correctly classified 85% of the hyperdivergent 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.

KEY WORDS: Photography, Hyperdivergent, Class II, Diagnosis

INTRODUCTION AND LITERATURE REVIEW

The craniofacial growth process is influenced by a variety of endogenous and exogenous factors that may alter the normal adaptive capacity of growing tissues and modify facial morphology.[1] Such altered skeletal pattern may be a risk factor on the development of abnormal physiological conditions.

It has been shown that specific craniofacial features such as increased anterior facial height,[1-3] 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.[4,5] Moreover, the hyperdivergent class II patient has been associated with higher prevalence and severity of sleep disturbances by airway obstruction.[6] 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.[7] Noninvasive alternatives since manual anthropometry,[8] to sophisticated methods such as electromagnetic digitizer,[9] laser scanning of the face [10] and digital stereophotogrammetry[11] have been suggested in order to establish an accurate diagnosis without radiation exposure.[12] However, 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.[7,12-14]

It has been a matter of concern whether the profile outline accurately reflects the underlying skeletal structures.[12,15] Actually, relationships have been found between analogous structures,[7,12,16-18] which suggest that soft-tissue profile can be used to estimate skeletal craniofacial pattern.[12,15] Conversely, some studies have reported only low to moderate correlations between photographic and cephalometric measurements.[7]

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

MATERIALS 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 (1) no previous orthodontic or surgical treatment, (2) all six maxillary anterior teeth present, (3) no craniofacial or cervical trauma, (4) no congenital anomalies and (5) 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

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* Discriminant analysis requires the number of subjects in the sample to be at least five times the number of independent variables in the study. (Hair JF, Anderson RE, Tatham RL, Black W. Análise discriminante múltipla e regressão logística. In: Hair JF, Anderson RE, Tatham RL, Black W. Análise multivariada de dados. 5.ed. São Paulo: Artmed; 1998. p. 219-20.)

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 class II group (ANB>4.5º and SN.GoMe>36º) and the other 72 subjects, 36 boys and 36 girls (ANB≤4.5º and/ or SN.GoMe≤36º) composed the second group. Detailed description of our photographic and radiographic protocol is given in a previous paper.*

Anatomical landmarks used in this investigation are shown in figure 1. Tables I and II present definitions of cephalometric and photographic reference points and planes. 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 (Fig. 2) and analogous photographic ones were used for sagittal and vertical assessment as well as for craniocervical posture analysis (Figs. 3, 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

*See pages 45 to 47 (Chapter 1).

through radiographs and photographs were performed by the same operator in a blind design.

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 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.[19]

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 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 class II, 22 other skeletal pattern) formed the test set, which was used for external validation purposes.

RESULTS

Sagital measurements made over photographs showed excellent repeatability and reproducibility (ICC ≥ 0.90). Most vertical diagnostic measurements showed satisfactory reliability (ICC > 0.8). Moderate to strong coefficients were observed for head and cervical posture variables (Table III).

Table IV summarizes descriptive statistics for sagittal and vertical photographic measurements, regarding the different skeletal facial patterns. Significant differences ($p \leq 0.05$ to $p \leq 0.001$) were found between the hyperdivergent 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 V. Significant differences between hyperdivergent 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.

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 VI).

The ten photographic variables which reached the level of significance in differentiating the groups (Table IV) 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 VII). Therefore, A’N’B’ and FMA’ showed the highest discriminating power in combination and were used to formulate the following canonical discriminant function (D):

$$D= - 8.308 + (0.486 \times A'N'B') + (0.130 \times FMA')$$

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 class II group, and -0.685 for the other group. Figure 5 shows scores distribution.

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:

$$Z_{critical} = (N_2 \times C_1) + (N_1 \times C_2) / (N_1+N_2)$$

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

$$= (43.95 – 26.715) / 89$$

$$= 17.235/ 89$$

$$= 0.2$$

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

Considering that the purpose of the present investigation was to develop a method for diagnosing the hyperdivergent 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 improve 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 VIII). When tested in another sample, method showed sensitivity of 83.3% and specificity of 72.7% (Table IX). Figure 7 illustrates the results of the discriminant analysis given the total sample (n=123).

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 study.[7,12-14,20-24] 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,[7,23] 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.[24] 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.[25,26]

The lowest ICC results were observed when assessing cervical lordosis reproducibility. This measurement requires an extremely accurate placement of C7 point, which is not an easy task. The seventh cervical vertebra (C7) has the most prominent spinous process in about 70% of the population.[27] However, the remaining 30% have either the sixth cervical vertebra (C6) or the first thoracic vertebra (T1) as the most prominent. During head extension, C6 spinous process moves anteriorly in normal healthy subjects, while C7 is the first cervical spinous process remaining stationary during this movement.[27] Thus, it is necessary to follow a rigid protocol to identify this structure, in order to avoid confusing with other vertebras. Such error showed lower relevance for angular measurements.

Once this paper aimed to identify hyperdivergent 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 class II patient from the other skeletal types through most photographic measurements studied, mainly the angular ones.

In general, the results of the cephalometric postural analysis in the current study corroborated the “soft-tissue stretching” hypothesis [28] since it was observed higher craniocervical angles, and lower craniovertical and cervicohorizontal angles for the hyperdivergent class II group. However, these differences were only statistically significant for three cephalometric variables (NSL.VER, NSL.CVT, NSL.OPT). Conversely, there were no significant differences between the groups concerning any postural photographic measurements.

It was found highly significant correlations ($p \leq 0.001$) for most analogous cephalometric and photographic measurements in this research, which agreed previous studies.[7,12] The strongest 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.[7,12,29,30]

Although sagittal and vertical jaw relationship were, in general, well reflected by the overlying soft tissues, Pearson correlation coefficients ranged from weak to moderate 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.[25]

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 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 79% 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 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 greater probability of the patient do not be a hyperdivergent 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.[7] Photographs might be better for large-scale epidemiologic studies, especially when there is a need for a low-cost and noninvasive method.[7]

CONCLUSIONS

- Highly significant correlations between analogous photographic and cephalometric measurements were found for most sagittal and vertical diagnostic variables. 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.

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FIGURES

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.

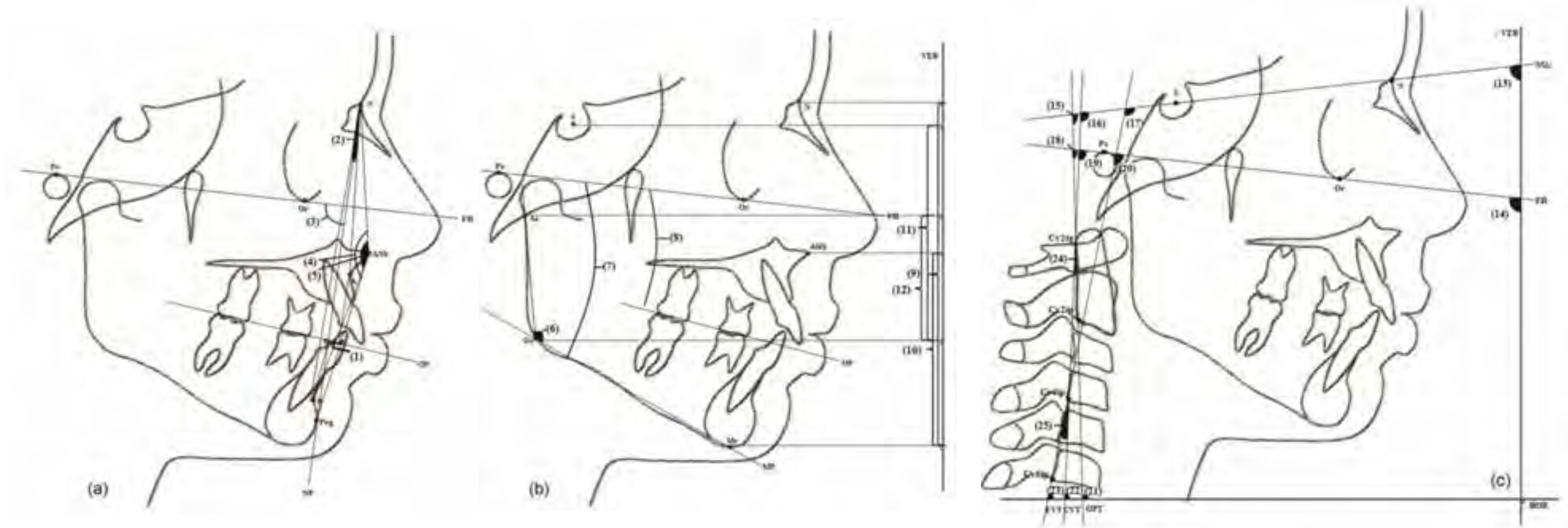

Figure 2. Cephalometric measurements. (a) Sagittal assessment: (1) Wits, maxillomandibular linear discrepancy; (2) ANB, maxillomandibular angular discrepancy; (3) FNP, facial angle; (4) N.ANS.Pog, (5) N.ANS.B, angles of facial convexity. (b) Vertical assessment: (6) Ar.Go.Me, gonial angle; (7) FMA, Frankfurt 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

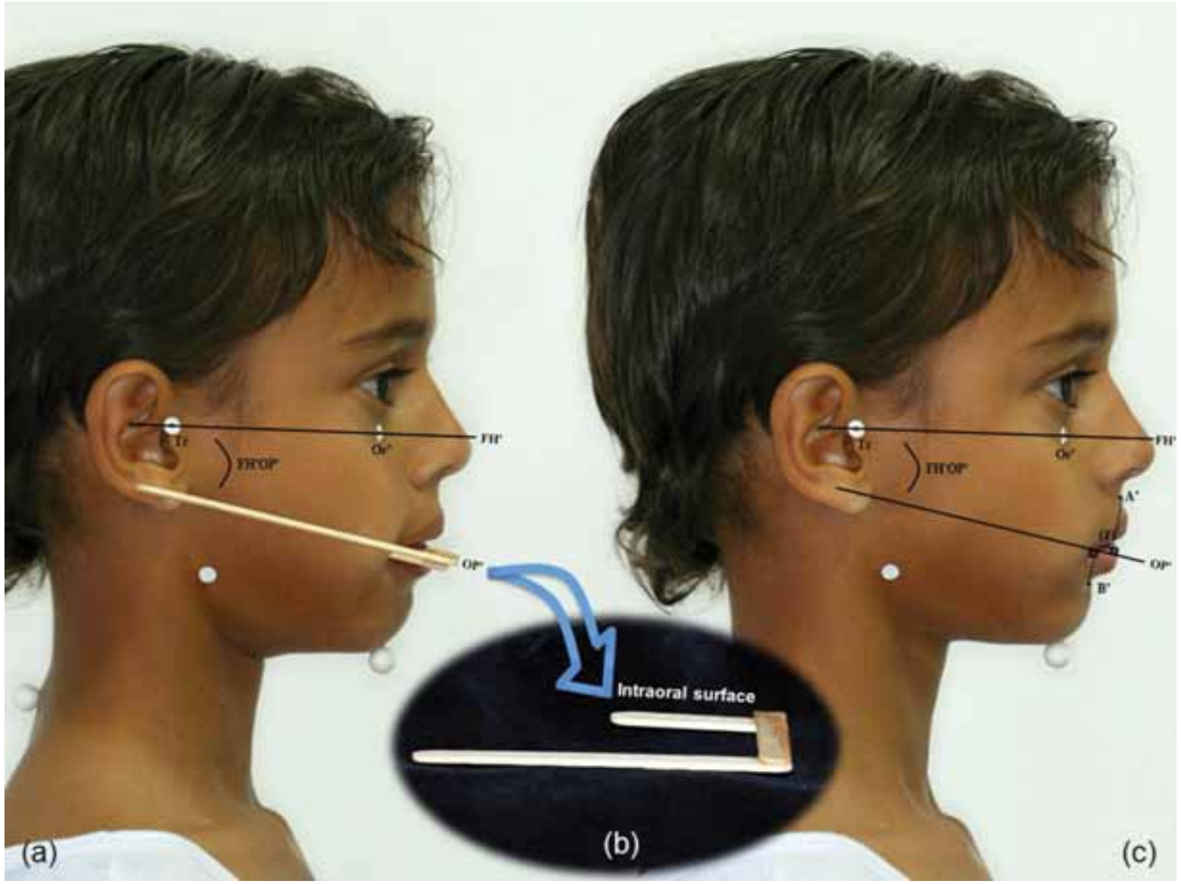

Figure 3. Photographic measurements. Sagittal assessment: (1) Wits', soft-tissue maxillomandibular linear discrepancy. (a) patient occluding a wooden spatulas device, (b) schematic representation of the device, (c) distance A'-B' obtained after the transfer of FH'OP' angle to the photography held in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

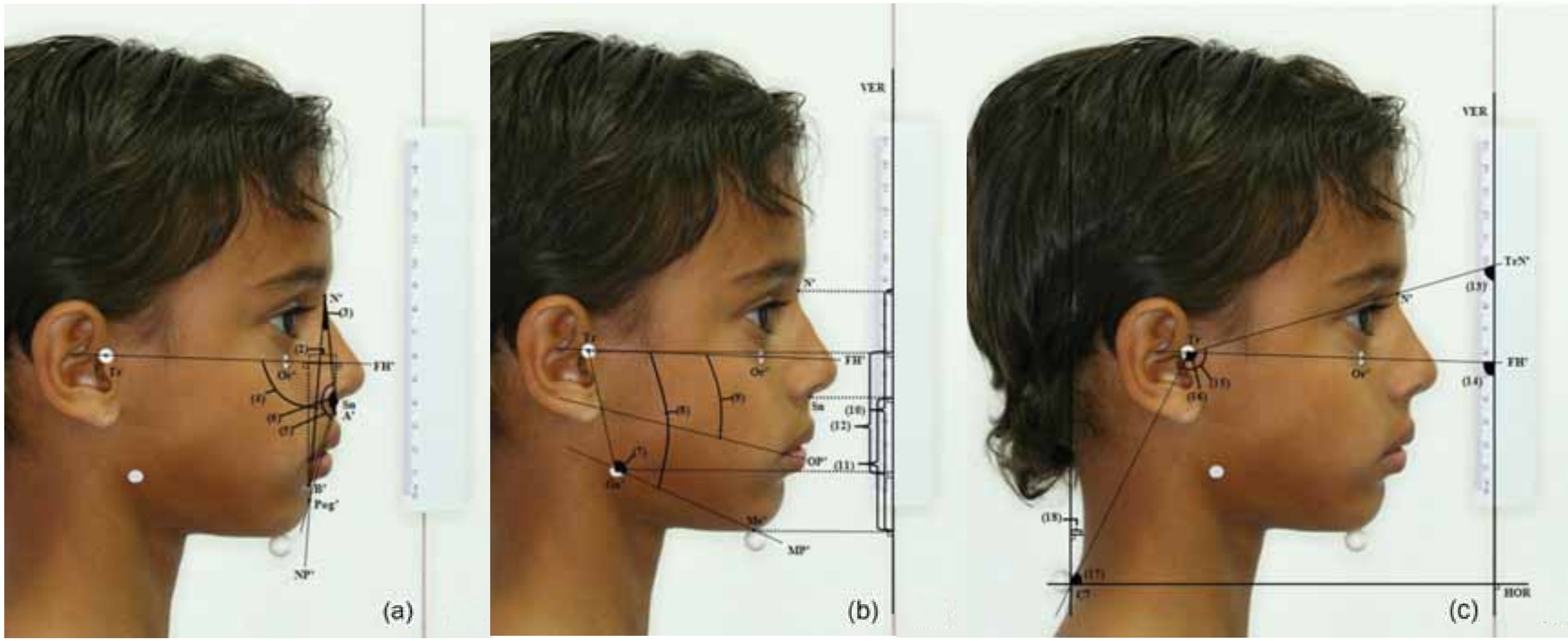

Figure 4. Photographic measurements continuation. (a) Sagittal assessment: (2) A'-B'perp, soft-tissue maxillomandibular linear discrepancy; (3) A'N'B', soft-tissue maxillomandibular angular discrepancy; (4) FNP', soft-tissue facial angle; (5) N'.Sn.Pog', (6) N'.Sn.B', soft-tissue angles of facial convexity. (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

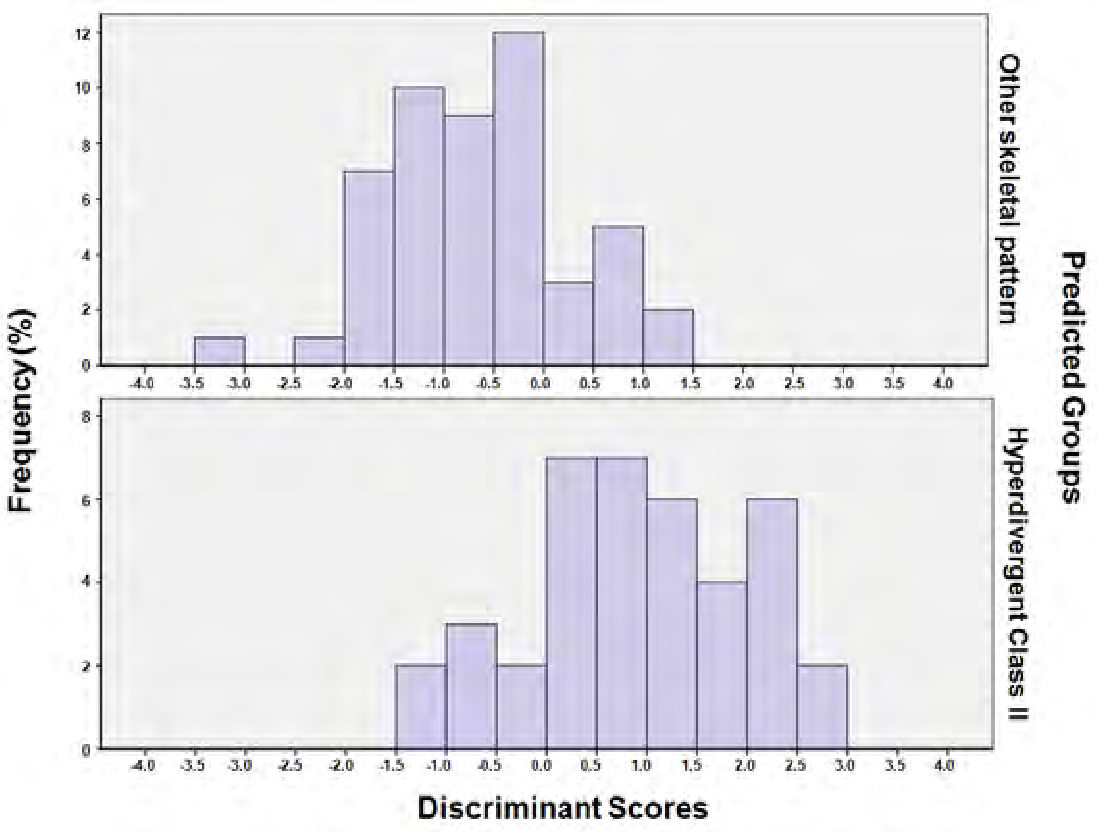

Figure 5. Histograms showing the distribution of discriminant scores for hyperdivergent class II patient and the other skeletal patterns

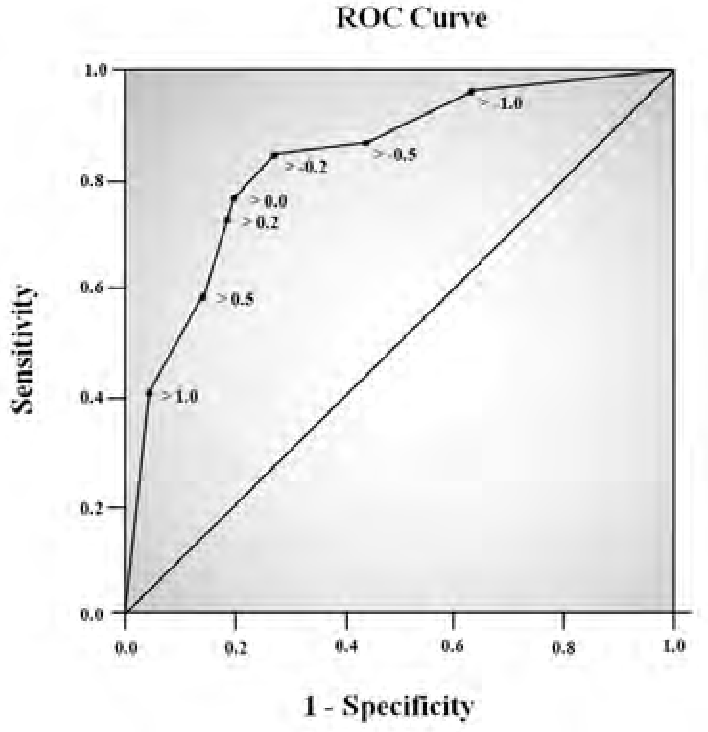

Figure 6. ROC curve. Sensitivity is plotted against 1 minus specificity for different cut-off values given the total sample (n=123)

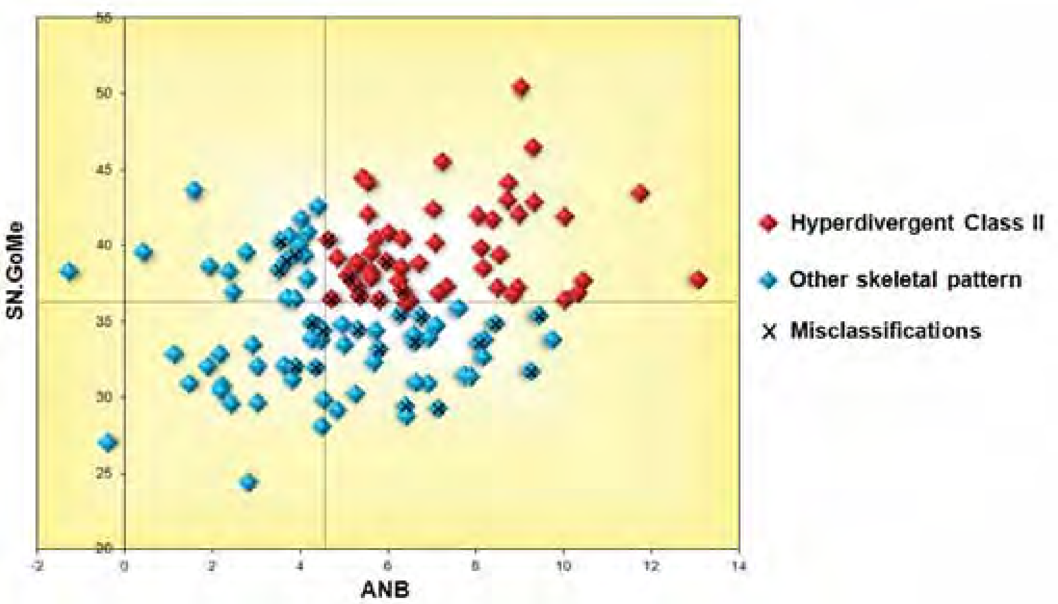

Figure 7. Discriminant analysis results

TABLES

Table I. Landmarks and reference planes used for cephalometric analysis

Anatomical landmarks	Symbol	Definition
Nasion	N	The most anterior point of the frontonasal suture
Articulare	Ar	The intersection between the external contour of the cranial base and the dorsal contour of the condylar head or neck
Porion	Po	The midpoint on the upper edge of the externals acoustic meatus
Orbitale	Or	The lowest point on the lower margin of the bony orbit (midpoint between right and left images)
Subspinale	A	The most posterior point on the anterior contour of the upper alveolar process
Supramentale	B	The most posterior point on the anterior contour of the lower alveolar process
Gonion	Go	The point on which the jaw angle is the most interiorly, posteriorly, and outwardly directed
Pogonion	Pog	The most anteriorly located point on the mandibular symphysis
Menton	Me	The most inferior point in the contour of the mandibular symphysis
Anterior Nasal Spine	ANS	Tip of the anterior nasal spine seen on the lateral radiographs
Sella turcica	S	The midpoint of Sella turcica
Second cervical vertebra body	Cv2ip	The most inferior and posterior point on the body of the second cervical vertebra (as defined by Solow) [14]
Odontoid process tangent	Cv2tg	The tangent point at the superior and posterior extremity of the odontoid process of the second cervical vertebra (as defined by Solow) [14]
Fourth cervical vertebra body	Cv4ip	The most inferior and posterior point on the body of the fourth cervical vertebra (as defined by Solow) [14]
Sixth cervical vertebra body	Cv6ip	The most inferior and posterior point on the body of the sixth cervical vertebra (as defined by Hellsing) [23]
Frankfurt horizontal plane	FH	Horizontal plane running through Porion and Orbitale
Mandibular plane	MP	Line extending between Gonion and Menton
Occlusal plane	OP	Line that joins the midpoint of the overlap of the mesio-buccal cusp of the first molar and the buccal cusp of the first premolar (as defined by Jacobson) [79]
Facial plane	NP	Line extending between Nasion and Pogonion
True vertical line	VER	Defined by a plumb line

True horizontal line	HOR	Horizontal line perpendicular to the true vertical (VER)
Cranial base line	NSL	Line extending between Sella turcica and Nasion
Cervical vertebra tangent	CVT	Posterior tangent to the odontoid process through Cv4ip (as defined by Solow) [14]
Odontoid process tangent	OPT	Posterior tangent to the odontoid process through Cv2ip (as defined by Solow) [14]
Lower cervical spine segment	EVT	Line through Cv4ip and Cv6ip (as defined by Hellsing) [23]

Table II. Landmarks and reference planes used for photographic analysis

Anatomical landmarks	Symbol	Definition
Soft-tissue nasion	N’	Point in the middle line located at the nasal root
Tragion	Tr	Posterior and superior point of the auricular tragus
Seventh cervical spinous process	C7	Tip of the spinous process of the seventh cervical vertebrae obtained by palpation of the most prominent spinous process of the cervical spine. Flexion-extension method was also performed [73].
Soft-tissue orbitale	Or’	Lowest point in bony orbit below right eye obtained by palpation
Soft-tissue subspinale	A’	Deepest point on anterior concavity of the upper lip
Soft-tissue supramentale	B’	Deepest point of the inferior sublabial concavity
Soft-tissue gonion	Go’	The most posterior and inferior point at the angle of the mandible obtained by palpation
Soft-tissue pogonion	Pog’	The most anteriorly located point on the chin
Soft-tissue menton	Me’	The most inferior point of the chin obtained by palpation
Subnasale	Sn	Point on the bottom of the cutaneous part of the nasal septum
Soft-tissue Frankfurt horizontal plane	FH’	Horizontal plane running through Tragion and soft-tissue Orbitale
Soft-tissue mandibular plane	MP’	Line extending between soft-tissue Gonion and Menton
Soft-tissue occlusal plane	OP’	Defined by the occlusion of a wooden spatula device
Soft-tissue facial plane	NP’	Line extending between soft-tissue Nasion and Pogonion
True vertical line	VER	Defined by a plumb line
True horizontal line	HOR	Horizontal line perpendicular to the true vertical (VER)

Table III. Repeatability and reproducibility of photographic method assessed by intraclass correlation coefficients (ICC)

Photographic Measurement	Repeatability (n = 27)			Reproducibility (n = 20)		
	ICC	Lower bound	Upper bound	ICC	Lower bound	Upper bound
Sagittal assessment:						
Wits’	0.904	0.803	0.955	0.910	0.790	0.963
A’-B’perp	0.945	0.884	0.974	0.934	0.844	0.973
A’N’B'	0.964	0.923	0.983	0.954	0.891	0.982
FNP'	0.903	0.801	0.954	0.899	0.768	0.959
N'.Sn.Pog'	0.980	0.958	0.991	0.970	0.927	0.988
N'.Sn.B'	0.981	0.959	0.991	0.955	0.893	0.982
Vertical assessment:						
Tr.Go'.Me'	0.946	0.886	0.975	0.814	0.594	0.921
FMA'	0.942	0.879	0.973	0.850	0.665	0.937
OPA’	0.813	0.634	0.910	0.855	0.675	0.940
LAFH' (Sn-Me')	0.855	0.710	0.931	0.909	0.789	0.963
AFH' (N'-Me')	0.838	0.678	0.922	0.878	0.723	0.950
PFH' (Tr-Go')	0.754	0.533	0.879	0.731	0.443	0.883
LAFH'/ AFH’	0.883	0.763	0.945	0.941	0.860	0.976
PFH'/ AFH'	0.796	0.604	0.901	0.782	0.535	0.907
PFH'/ LAFH'	0.832	0.668	0.919	0.826	0.618	0.927
Head and cervical posture assessment:						
TrN'VER	0.670	0.399	0.834	0.675	0.349	0.856
FH'VER	0.751	0.528	0.878	0.721	0.426	0.878
C7TrN'	0.700	0.446	0.851	0.774	0.520	0.903
C7FH'	0.768	0.557	0.887	0.816	0.598	0.922
TrC7HOR	0.752	0.530	0.878	0.793	0.555	0.912
CL	0.777	0.571	0.891	0.508	0.105	0.770

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

	Group I Hyperdivergent 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	166	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; * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$

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

	Group I Hyperdivergent 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 class II, 55 other skeletal pattern). The remaining sample did not present the sixth cervical vertebra visible on the radiograph.

Table VI. Correlation coefficients between cephalometric and photographic measurements

Measurement parameters		All subjects (n = 123)		Hyperdivergent 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 class II, 55 other skeletal pattern). The remaining sample did not present the sixth cervical vertebra visible on the radiograph.

Table VII. 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 VIII. Identification of Hyperdivergent Class II patients by a canonical discriminant function: Calibration set

Cephalometric diagnosis (Gold standard)	Canonical discriminant function (D) diagnosis		Total
	Hyperdivergent Class II (D>-0.2)	Other skeletal patterns (D≤-0.2)	
Hyperdivergent Class II (ANB>4.5º, SN.GoMe>36º)	33 (84.6%)	6 (15.4%)	39 (100%)
Other skeletal patterns (ANB≤4.5º, SN.GoMe≤36º)	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 IX. Identification of Hyperdivergent Class II patients by a canonical discriminant function: Test set

Cephalometric diagnosis (Gold standard)	Canonical discriminant function (D) diagnosis		Total
	Hyperdivergent Class II (D>-0.2)	Other skeletal patterns (D≤-0.2)	
Hyperdivergent Class II (ANB>4.5º, SN.GoMe>36º)	10 (83.3%)	2 (16.7%)	12 (100%)
Other skeletal patterns (ANB≤4.5º, SN.GoMe≤36º)	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) = 62.5%
Negative predictive value	TN/ (TN + FN) = 88.9%
Total accuracy	TP+TN/ (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

4 Considerações Finais

4 Considerações Finais

Fundamentados nos resultados e conclusões apresentados pelos artigos, podemos tecer as seguintes considerações finais:

- Tanto a repetibilidade quanto a reprodutibilidade do método fotográfico mostraram-se bastante satisfatórias, exceto para algumas variáveis utilizadas no diagnóstico das relações posturais;

- Correlações altamente significativas foram encontradas entre medidas fotográficas e cefalométricas análogas, considerando a maioria das variáveis utilizadas para diagnóstico do padrão esquelético facial nos sentidos sagital e vertical. Entretanto, não foram observadas correlações significativas entre algumas medidas utilizadas para avaliação postural. Portanto, é necessário que haja cautela quando da inferência do alinhamento das vértebras cervicais a partir de avaliações fotográficas;

- A análise de regressão revelou que as variáveis fotográficas que melhor explicaram a variabilidade de seus análogos cefalométricos foram os ângulos A'N'B' e FMA'. Quando combinadas em uma função canônica discriminante, estas medidas apresentaram a maior capacidade de diagnosticar indivíduos padrão esquelético classe II hiperdivergente dentre os demais padrões esqueléticos faciais;

- O método fotográfico pode ser considerado uma alternativa viável, prática e confiável para o diagnóstico de pacientes padrão esquelético classe II hiperdivergente em estudos epidemiológicos de larga escala, uma vez que um protocolo adequado de padronização da técnica seja seguido;

- Estudos adicionais são necessários a fim de testar a precisão do método no diagnóstico de outros padrões esqueléticos faciais.

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5 Referências *

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6 Apêndices

Apêndice 1- Termo de consentimento livre e esclarecido

unesp UNIVERSIDADE ESTADUAL PAULISTA
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TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Eu,_____________________________________, portador de RG nº ____________, _____(idade), residente à Rua (Av.)_______________________________________, nº_____, na cidade de _____________, Estado: ___, autorizo a participação do menor _______________________________, portador de RG nº ____________, _____(idade), residente à Rua (Av.)_______________________________________, nº_____, na cidade de _____________, Estado: ___, prontuário nº_______, pelo qual sou responsável como __________(grau de parentesco), como voluntário na pesquisa intitulada: *"MÉTODOS NÃO RADIOGRÁFICOS PARA DIAGNÓSTICO DO PADRÃO ESQUELÉTICO CLASSE II HIPERDIVERGENTE"*, tendo o Dr. João Roberto Gonçalves como pesquisador responsável. Sendo assim, declaro estar ciente de que:

1- A pesquisa em questão tem como objetivo a realização do diagnóstico de um problema esquelético conhecido como *classe II esquelética hiperdivergente,* através de fotografias padronizadas e utilização de um instrumento semelhante a uma régua (paquímetro facial), tendo em vista a possibilidade destes indivíduos virem a desenvolver problemas na articulação da boca (mandíbula), assim como manifestarem alterações na postura da coluna cervical, o que implica em problemas durante o crescimento da face. Portanto, o diagnóstico precoce através de métodos simplificados pode gerar grandes benefícios a estes indivíduos;

2- Os procedimentos a serem realizados na criança serão: tomadas fotográficas da região de cabeça e pescoço, preenchimento de fichas clínicas com as mensurações obtidas através da utilização do instrumento semelhante a uma régua (paquímetro facial), e avaliação das radiografias laterais da face, obtidas como parte da documentação necessária ao planejamento de todo tratamento ortopédico e ortodôntico;

3- Estou ciente de que a criança, a qual sou responsável, será tratada no próprio centro responsável pela solicitação das radiografias;

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CÂMPUS DE ARARAQUARA
FACULDADE DE ODONTOLOGIA

Rua Humaitá, 1680 - 14801-903 Araraquara-SP - FONE: 0xx16-3301 6434 - FAX: 0xx16-3301 6433

4- A minha participação na pesquisa é voluntária, e poderei desistir dela a qualquer momento, sem dar explicações sobre os motivos, e ainda, sem comprometer qualquer tratamento do paciente na Faculdade de Odontologia de Araraquara – UNESP;

5- Poderei fazer perguntas ou solicitar esclarecimentos sobre quaisquer dúvidas antes e durante o desenvolvimento da pesquisa;

6 - O pesquisador responsável garante o sigilo das informações confidenciais, zelando pela privacidade do paciente. Garante ainda que a identidade do paciente será preservada quando a pesquisa for exposta em congressos ou em publicações científicas;

7 - Confirmo que recebi todas as informações relacionadas à pesquisa. Sendo assim, autorizo os pesquisadores a realizarem os procedimentos necessários.

Araraquara, ____ de ___________ de 2010

____

Responsável pelo paciente

____

Dr. João Roberto Gonçalves

Pesquisador Responsável

Telefones para contato:

Comitê de Ética em Pesquisa: (16) 3301-6432/ 3301-6434

Pesquisador responsável: (16) 33016325

Membros da equipe:

- Liliane Gomes- (16) 3357-6899
- Karla Carpio- (16) 88223218

Apêndice 2- Termo de autorização para uso de imagem referente às fotografias e radiografias apresentadas no capítulo 1

TERMO DE AUTORIZAÇÃO PARA USO DE IMAGEM

Eu, Jurema Gentil Biagiolli, portador de RG nº 16712459, residente à Rua (Av.) Alfredo Gabriel Abadi, nº 109, na cidade de Araraquara, autorizo que as fotografias e radiografias do menor Eduarda da Silva Biagiolli, pelo qual sou responsável como Avó (grau de parentesco), sejam utilizadas para finalidade didática e científica, podendo ser divulgadas em aulas, congressos, e também publicadas em livros e artigos científicos na área de Odontologia.

Araraquara, 25 de julho de 2012

Responsável pelo paciente

Apêndice 3- Termo de autorização para uso de imagem referente às fotografias apresentadas no capítulo 2

TERMO DE AUTORIZAÇÃO PARA USO DE IMAGEM

Eu, Angelina Miel portador de RG nº 20321.622 residente à Rua (Av.) av. 38, nº 1841, na cidade de Araraquara autorizo que as fotografias e radiografias do menor Yago Vargas Franco pelo qual sou responsável como avó (grau de parentesco), sejam utilizadas para finalidade didática e científica, podendo ser divulgadas em aulas, congressos, e também publicadas em livros e artigos científicos na área de Odontologia.

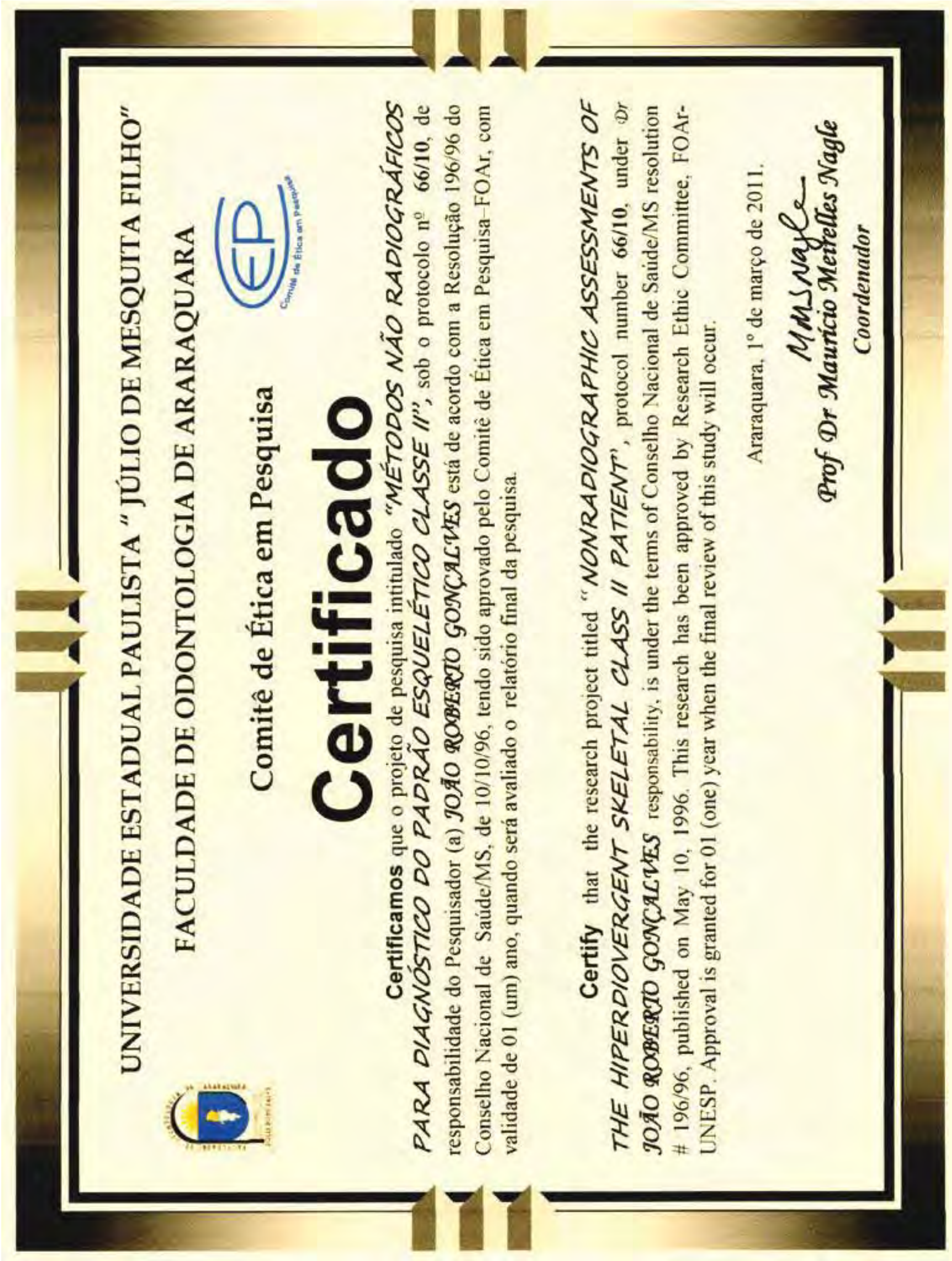
Araraquara, 26 de julho de 2012

Angelina Miel

Responsável pelo paciente

7 Anexos

Anexo 1- Certificado de aprovação pelo Comitê de Ética em Pesquisa



UNIVERSIDADE ESTADUAL PAULISTA " JÚLIO DE MESQUITA FILHO"

FACULDADE DE ODONTOLOGIA DE ARARAQUARA

Comitê de Ética em Pesquisa

Certificado

Certificamos que o projeto de pesquisa intitulado *"MÉTODOS NÃO RADIOGRÁFICOS PARA DIAGNÓSTICO DO PADRÃO ESQUELÉTICO CLASSE II"*, sob o protocolo nº 66/10, de responsabilidade do Pesquisador (a) ***JOÃO ROBERTO GONÇALVES*** está de acordo com a Resolução 196/96 do Conselho Nacional de Saúde/MS, de 10/10/96, tendo sido aprovado pelo Comitê de Ética em Pesquisa-FOAr, com validade de 01 (um) ano, quando será avaliado o relatório final da pesquisa.

Certify that the research project titled *" NONRADIOGRAPHIC ASSESSMENTS OF THE HIPERDIOVERGENT SKELETAL CLASS II PATIENT"*, protocol number **66/10**, under *Dr* ***JOÃO ROBERTO GONÇALVES*** responsability, is under the terms of Conselho Nacional de Saúde/MS resolution # 196/96, published on May 10, 1996. This research has been approved by Research Ethic Committee, FOAr-UNESP. Approval is granted for 01 (one) year when the final review of this study will occur.

Araraquara, 1º de março de 2011.

Prof Dr Maurício Meirelles Nagle

Coordenador

Araraquara, 19 de setembro de 2012.

LILIANE DE CARVALHO ROSAS GOMES