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Correlation of Cephalometric and Photographic Measurements in Different Skeletal Patterns

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Abstract

Introduction: *Photographic analysis has been considered as an essential tool for orthodontic diagnosis and treatment planning, lending to its cost effective and non-hazardous nature. It is imperative to assess the hard and soft tissue relationships in order to evaluate if photographs can be used as an alternative to radiographic analysis. The aim of this study was to investigate the interrelationship of cephalometric hard tissue measurements with their soft tissue counterparts in individuals with different skeletal patterns.*

Materials and Method: *Lateral cephalograms and standardized photographic records were obtained for 150 subjects (79 girls, 71 boys, 9-16 years) which were divided into three groups of Class I, II and III skeletal jaw bases. Analogous photographic and cephalometric values were compared to evaluate Peason's correlation coefficients. Correlations were compared to evaluate the influence of skeletal pattern as well as sexual dimorphism on hard and soft tissue relationships.*

Results: *Strong correlation was observed amongst most measurements. Sexual dimorphism was prominent in photographic variables. Amongst all three groups combined, the photographic variable that was most analogous with its cephalometric variable was N'perp-A'(r = 0.988) and N'perp-Pog' (r = 0.988) and least analogous was LAFH'/AFH' (r = 0.416).*

Conclusion: *Photographic method is a reliable and repeatable alternative to cephalometric technique, irrespective of one's gender or skeletal pattern. Anteroposterior jaw discrepancy can be analysed with soft tissue photographs more efficiently as compared to vertical discrepancies*

Keywords: *Photography, Cephalometry, Skeletal pattern, Diagnosis.*

Introduction

For decades, photography has been considered as an essential diagnostic tool in the field of orthodontics for clinical as well as research purpose.Assessment of craniofacial morphology plays a vital role in treatment planning and can be achieved with cephalometric as well as photographic means. The photographic method has an advantage of being able to assess the soft tissue profile for predicting treatment plan with respect to esthetic improvement. Quantitative analyses of the soft-tissue profile has shown the influence of various classes of malocclusion, which is especially important to measure the influence of orthodontic treatment on facial esthetics(1).

However, over the years, advancement in various imaging techniques along with standardization in norms has led to an increasing popularity of radiographic methods, putting a fall back on facial photography. Radiographs proved to be more precise and reproducible, and had a major advantage of being able to see what's going on the inside, giving a clue about the skeletal discrepancies. This made orthopentamograms and lateral cephalograms a primary diagnostic choice in the field of orthodontics, leaving only an adjunctive role for photographic soft tissue analysis.

In the recent times, photographic diagnosis is being revisited due to the increasing concerns about radiation hazards. More and more research is being encouraged to find a standardized quantitative analysis to increase its clinical significance. Such quantitative analysis may serve as a powerful method to address craniofacial disorders, establish treatment planning, evaluate surgical results and orthodontic outcomes, and study facial growth. Thus, it may be as effective in orthodontics as in several other medical fields(2).

Various cephalometric analyses methods have shown a strong correlation between hard tissue structures and their soft tissue counterparts. However, comparisons involving cephalometric and photographic measurements have seldom been performed, and conflicting results have been found(3). Hard tissue analysis alone cannot help predict the soft tissue treatment outcome. According to **Kasai**, the relationship between the hard tissue and soft tissue profile is variable because some soft tissue structures are closely related to hard tissue while others are influenced by their length, thickness, and function(4). Photographic analysis of hard tissue morphology might be a comparatively safe, non-invasive alternative for orthodontic diagnosis.

Another key consideration is that due to differences in areas and degree of soft tissue compensation, this hard to soft tissue relation might be subject to variations in sagittal and vertical skeletal patterns. If any correlation exists, it is important to study whether the skeletal maxillo-mandibular relation has any significant influence over it. Hence, this study aimed to investigate the interrelationship of cephalometric hard tissue measurements with their soft tissue counterparts in individuals with different skeletal patterns.

Materials and Method

This in-vitro study was conducted on patients being admitted in the institution for treatment of various maloccusions. A total of 150 patients, 79 girls and 71 boys, between the age group of 9 to 16 years were selected (mean age 12.7 years). Patients with no previous history of orthodontic treatment, no congenital anomalies and no craniofacial or neurological defects were included in the study. Parents or legal guardians were informed about the procedure and written consent was taken from them. Pretreatment photographic records and lateral cephalograms were obtained and the patients were equally divided on the basis of their skeletal jaw bases into three groups of 50 subjects each as skeletal class I, II and III.

Photographic records were obtained using a digital camera (EOS 1100D, Canon, Tokya, Japan) mounted with a macro lens (EF-S 18-55 mm f/3.5-5.6 Macro Lens, Canon) and ring flash (Macro Ring Lite YN-14EX TTL LED, Yongnuo) in program mode. The camera was set 2 metres away from the subject, on a tripod stand for stability and was adjusted according to the subject's height. The 100-mm macro lens was chosen to avoid facial deformations and maintain natural proportions(2).

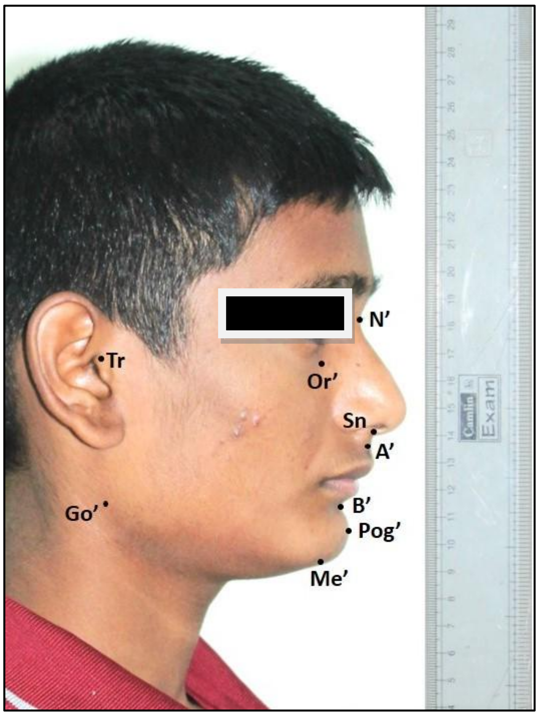

Figure no. 1: Photographic landmarks. N'-soft tissue Nasion, Or'-soft tissue Orbitale, Tr-Tragion, Go'- soft tissue Gonion, Me'- soft tissue Menton, Pog'- soft tissue Pogonion, B'- soft tissue point B, A'- soft tissue point A, Sn-Subnasale

Figure no. 2: Modified Protractor placed on tip of nose and soft issue Pogonion to assess Natural Head Position

For the purpose of standardization, profile photographs were taken from the right side in a natural head position (NHP), with teeth in centric occlusion and relaxed lips and chin (Figure no. 1). In order to achieve calibration of the image at life size later, this photograph was clicked with a scale hanging with a plumb line parallel to the subject's midsagittal plane. To obtain an NHP, a method given by **Gomes et al**[2] was followed, where the patient was asked to stand 1.2 metres away from and facing a mirror and look straight into the reflection of their own eyes. To be able to reproduce one's NHP, a protractor with a plumb bob was placed from tip of nose to soft tissue pogonion and the angle made by the plumb thread was measured (Figure no. 2). To mark the occlusal plane, a photograph was clicked with the subject holding a Faux plane between their teeth (Figure no. 3).

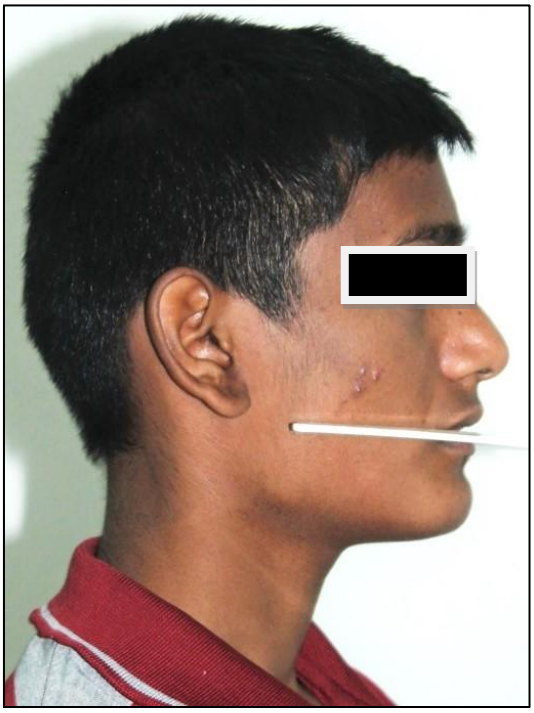

Figure no. 3: Patient occluding on a Faux plane to obtain Occlusal plane.

Figure no. 4: Digital Radiograph

Digital lateral cephalograms were taken with a CS 8000C (Carestream Dental, Carestream Health, Atlanta, Ga) with a charged coupled device (CCD) sensor chip as an image receptor. The exposure parameters for all lateral cephalograms were set to 80 kV, 10mA and 0.5 seconds.

Lateral cephalograms were shot in a NHP with teeth in centric occlusion and lips and chin at rest. To reproduce the same NHP as the one in facial photographs, the protractor with a plumb bob was placed on tip of nose and soft tissue pogonion to achieve the same angle with plumb thread which was obtained earlier. For the purpose of calibration, radiopaque markings seen on the pointer which were each 10 milimetres apart were used (Figure no. 4).

The radiographic as well as photographic analysis was done using Radioceph 2.0 (Radio Memory Ltda, Belo Horizonte, MG, Brazil) software for Windows. Calibration was done to maintain life size values and landmarks were identified for every image, radiographic as well as photographic. Customized analysis was updated in the software and once the landmarks were fed into it, all the conventional linear and angular cephalometric measurements as well as its analogous photographic measurements were automatically calculated. These measurements were used for sagittal and vertical assessment.

The landmark identification and analyses for all cephalograms and radiographs were performed by a single operator. In order to carry out repeatability analysis, new landmark identification was done for 30 subjects (17 girls, 13 boys) by a second operator two weeks later to avoid any bias.

Statistical Analysis

The data was tabulated and analysed by Statistical Product and Service Solutions, version 21 (SPSS) for Windows (Armonl NY-IBM corp software). Descriptive statistics were found for each cephalometric and analogous photographic variables. Pearson correlation coefficients were evaluated by comparing cephalometric and photographic values in Class I, II and III subjects. Independent t-test was used to assess sexual dimorphism. To assess the repeatability, intra class correlation coefficients were evaluated from repeated landmark identifications of 30 patients.

Results

Intra class correlation coefficients showed high repeatability of cephalometric as well photographic technique with an ICC of 0.83 and 0.89, respectively.

Tables 1 and 2 describe the mean, standard deviation and gender differences for every cephalometric and photographic values amongst all subjects. Overall, no gender difference was found for cephalometric variables. However, significant mean difference was found for the photographic variables A'N'B', LPFH' and PFH'/AFH' ($p <= 0.05$).

Table 1: Descriptive Statistics for Cephalometric measurements

	MALES (n=71)		FEMALES (n=79)		GENDER DIFFERENCE	
MEASUREMENTS	**MEAN**	**SD**	**MEAN**	**SD**	**MEAN**	**SIGNIFICANCE**
SAGITTAL ASSESSMENT						
Wits	.7390	5.45670	1.5505	5.31432	.81149	NS
ANB	.5141	5.68241	1.4829	5.43652	.96883	NS
FH-Npog	84.2221	4.50348	84.0110	4.37499	-.21110	NS
N perp-A	-5.6034	4.71463	-4.9696	4.62708	.63376	NS
N perp-Pog	-9.6569	7.97187	-9.9819	7.78273	-.32500	NS
NA- A Pog	-1.1554	11.86209	.9524	11.55151	2.10776	NS
AB- Npog	-1.8952	8.56099	-3.3582	8.14231	-1.46302	NS
VERTICAL ASSESSMENT						
Ar-Go-Me	125.4011	5.61646	125.8792	5.86628	.47811	NS
Ar-Go-N	55.0858	4.75827	55.1511	4.90391	.06536	NS
N-Go-Me	70.3151	5.38468	70.7277	4.92445	.41265	NS
FMA	24.8496	6.68339	25.3694	6.20400	.51979	NS
FH-Go-Me	25.2297	6.72476	25.7600	6.23827	.53028	NS
FH-OP	7.9977	4.42549	8.1423	4.16322	.14453	NS
LAFH (ANS-Me)	58.9421	5.92883	58.8182	5.66833	-.12388	NS
LPFH (Ar-Go)	42.0437	5.40123	41.0119	5.61945	-1.03176	NS
AFH(N-Me)	103.0587	7.78122	103.0353	7.48055	-.02342	NS
PFH (S-Go)	71.9663	6.09379	70.8844	6.26803	-1.08191	NS
PFH/AFH	.6979	.06441	.6867	.06097	-.01118	NS
LAFH/AFH	.5711	.03040	.5737	.03552	.00254	NS
LPFH/LAFH	.7137	.12446	.6953	.12173	-.01835	NS

NS = Not significant

Table 2: Descriptive Statistics for Photographic measurements

	MALES (n=71)		FEMALES (n=79)		GENDER DIFFERENCE	
MEASUREMENTS	**MEAN**	**SD**	**MEAN**	**SD**	**MEAN**	**SIGNIFICANCE**
SAGITTAL ASSESSMENT						
Wits'	2.6107	6.30253	3.4846	5.80034	.87385	NS
A'N'B'	2.1964	6.62235	2.0742	6.39807	-0.1226	*
FH-N'Pog'	84.3966	3.98506	84.3892	3.93439	-.00738	NS
N' perp-A'	-4.7663	5.16154	-3.6570	4.95068	1.10938	NS
N' perp-Pog'	-10.313	7.78496	-10.140	7.28891	.17245	NS
N'A'- A' Pog'	3.0144	13.4164	5.3516	12.5033	2.33728	NS
A'B'- N'pog'	-3.7473	9.38263	-5.2501	8.69393	-1.50280	NS
VERTICAL ASSESSMENT						
Tr-Go'-Me'	126.536	5.39324	127.680	5.65433	1.14337	NS
Tr-Go'-N'	57.2576	4.15746	57.6281	4.00317	.37050	NS
N'-Go'-Me'	69.3797	5.17939	70.1424	4.85833	.76269	NS
FMA'	25.5614	5.88199	26.1573	5.20562	.59593	NS
FH-Go'-Me'	25.9476	5.82353	26.5143	5.14384	.56670	NS
FH-OP'	7.9369	3.76803	8.3533	3.89734	.41639	NS
LAFH' (Sn-Me')	59.9087	6.00171	59.7358	5.61772	-.17291	NS
LPFH' (Tr-Go')	41.9006	5.83128	41.6111	5.99410	-0.2895	*
AFH' (N'-Me')	103.871	7.83850	103.362	7.12230	-.50913	NS
PFH'/AFH'	.4046	.07002	.3980	.06613	-0.0066	*
LAFH'/AFH'	.5713	.02028	.5722	.02211	.00088	NS
LPFH'/LAFH'	.6955	.12599	.6792	.11562	-.01625	NS

* = Significant ($p<0.05$)
NS = Not significant

Table 3 shows that correlation between most sagittal and vertical variables for all three groups were highly significant ($p < 0.001$). Highest coefficients were found between FMA v/s FMA' ($r = 0.994$) and FH-Go-Me v/s FH-Go-Me'($r = 0.994$) for Class I subjects, between N perp-A v/s

N'perp-A'(r = 0.998) for Class II subjects and between N perp-Pog v/s N'perp-Pog'(r = 0.999) and FH-Go-Me v/s FH-Go-Me'(r = 0.999) for Class III subjects. Moderate correlation was found between PFH v/s LPFH' (r = 0.462) for Class III subjects. No correlation was seen between LAFH/AFH v/s LAFH'/AFH' (r = -0.253) for Class II subjects.

Amongst all three groups combined, the photographic variable that was most analogous with its cephalometric variable was N'perp-A'(r = 0.988) and N'perp-Pog' (r = 0.988) and least analogous was LAFH'/AFH' (r = 0.416).

Table 3: Correlation Coefficients between Cephalometric and Photographic values

MEASUREMENT PARAMETERS		CLASS I		CLASS II		CLASS III		ALL SUBJECTS	
CEPHALOMETRIC	PHOTOGRAPHIC	CORRELATION	SIGNIFICANCE	CORRELATION	SIGNIFICANCE	CORRELATION	SIGNIFICANCE	CORRELATION	SIGNIFICANCE
SAGITTAL ASSESSMENT									
Wits	Wits'	.936	***	.972	***	.991	***	0.966	***
ANB	A'N'B'	.781	***	.981	***	.986	***	0.916	***
FH-Npog	FH-N'Pog'	.690	***	.962	***	.742	***	0.798	***
N perp-A	N' perp-A'	.977	***	.998	***	.990	***	0.988	***
N perp-Pog	N' perp-Pog'	.988	***	.989	***	.999	***	0.988	***
NA- A Pog	N'A'- A' Pog'	.980	***	.985	***	.991	***	0.985	***
AB- Npog	A'B'- N'pog'	.942	***	.975	***	.994	***	0.970	***
VERTICAL ASSESSMENT									
Ar-Go-Me	Tr-Go'-Me'	.859	***	.883	***	.995	***	0.912	***
Ar-Go-N	Tr-Go'-N'	.959	***	.943	***	.995	***	0.965	***
N-Go-Me	N'-Go'-Me'	.837	***	.862	***	.994	***	0.897	***
FMA	FMA'	.994	***	.808	***	.998	***	0.933	***
FH-Go-Me	FH-Go'-Me'	.994	***	.800	***	.999	***	0.931	***
FH-OP	FH-OP'	.987	***	.914	***	.993	***	0.964	***
LAFH (ANS-Me)	LAFH' (Sn-Me')	.905	***	.951	***	.981	***	0.945	***
LPFH (Ar-Go)	LPFH' (Tr-Go')	.920	***	.987	***	.907	***	0.938	***
AFH(N-Me)	AFH' (N'-Me')	.956	***	.964	***	.981	***	0.967	***
PFH (S-Go)	LPFH' (Tr-Go')	.644	***	.694	***	.462	**	0.600	***
PFH/AFH	PFH'/AFH'	.599	***	.537	***	.865	***	0.667	***
LAFH/AFH	LAFH'/AFH'	.582	***	.253	NS	.921	***	0.416	**
LPFH/LAFH	LPFH'/LAFH'	.983	***	.957	***	.988	***	0.976	***

*** = Highly significant (p<0.001)
** = Very significant (p<0.01)
NS = Not significant

Discussion

Cephalometric analysis has long been a gold standard for orthodontic diagnosis and treatment planning. However, photographic investigation holds an imperative status in the evaluation of harmonic relationships between skeletal and soft tissue craniofacial changes with the added advantage of low cost and no radiation exposure(5).Through the repeatability test it was found that the linear and angular measurements useful for characterizing facial morphology can be reliably measured from facial photographs, which corroborates previous studies(1,3,6–10). This evidence is a strong enough to consider photographic method as a practical and significant alternative when radiography might prove too invasive or is impractical(2).

Direct arthropometry is another three dimensional alternative to radiographic diagnosis, but requires time, patience and relatively higher precision.

Hence, photography, even though two dimensional, becomes more convenient, especially for longitudinal studies, as the subject is still and accurate, repeatable measurements can be recorded(6,7). However, this method has a drawback of image distortion, leading to variations in measurements of structures near and far from the camera lens(9).This can cause a problem when the structures located in different planes of space are compared with each other(2). In this study, a lateral photograph is used and most landmarks are either located at the midline or are used for angular measurements, so this issue should seldom affect the results(2,9).

Another area of concern is the head posture as it can greatly affect the landmark location and measurement values(8). This was taken care of by the use of a protractor with a plumb bob while recording a radiograph and a photograph to replicate the same angulation, and in turn, the Natural Head Position. Furthermore, jaw opening, lip straining or puckering of chin would strain the muscles and shift the facial landmarks(2,8). This was avoided by maintaining a relaxed face of the subjects while taking the records. To reduce operator bias, repeatability test was conducted on radiographic as well as photographic records and the results showed good reproducibility.

In our study, cephalometric values showed no gender difference, showing a similar distribution amongst male and female subjects. However, significant differences were found for photographic variables A'N'B', LAFH', LPFH' and PFH'/AFH' ($p <= 0.05$).

Overall, no gender difference was found for cephalometric variables. However, significant difference was found for the photographic variables A'N'B', LPFH' and PFH'/AFH' with higher values for male subjects ($p <= 0.05$).Previous authors have also found sexual dimorphism in various facial photographic parameters. **Gomes LDCR et al**(2) reported larger values of A'N'B', LAFH', PFH' and PFH'/AFH' in male subjects. **Fernandez-Riveiro et al**(11)observed prominent labial, nasal and chin areas with greater facial heights in male subjects. They discerned that the subnasale (Sn) point was more prominent and forwardly placed in males, partially causing an increase in A'N'B'angle. Studies given by **Ferrario et al**(5), **Fernandez-Riveiro et al**(11)and **Bishara et al**(12,13) have also reported increased values of LAFH' and PFH' in male subjects. However, no significant gender difference was observed for ratios LAFH'/AFH' and LPFH'/LAFH' suggesting that even though some structures are prominent amongst males, the proportions remain the same as females.

In this study, the age group selected was 9 to 16 years old due to the close interconnection of hard and corresponding soft tissue growth during this period. The overall Pearson's coefficients of correlation were strong ($r >= 0.6$), but individual correlations ranged from weak to strong ($0.25 > r > 0.99$). This suggests that even though there was a strong tendency for analogous cephalometric and photographic values to vary together, individual variations were present.

The study subjects were divided into three groups according to their skeletal jaw bases as Class I, II and III in order to check the influence of skeletal pattern on the level of correlation between cephalometric and photographic values. Results showed a very high correlation ($p < 0.001$) between most variables. For Class I subjects, correlation of mandibular plane angles was the highest. Highest correlation was seen between sagittal positioning of maxilla for Class II subjects and between sagittal positioning of mandible for Class III subjects. This suggests that well developed, prominent jaws show superior correlation of hard and soft tissues as compared to underdeveloped jaws. Moderate correlation was found between PFH v/s LPFH' for Class III subjects whereas no correlation was seen between LAFH/AFH v/s LAFH'/AFH' for Class II subjects. This suggests that the disharmony in skeletal proportions might be compensated by soft tissue adaptation. When correlations were combined for all subjects, it was observed that the sagittal positioning of maxilla and mandible showed highest correlation while facial proportion LAFH'/AFH' showed least correlation. Thus, this suggests that sagittal maxillary and mandibular relation can be judged efficiently by soft tissue alone.

A study carried out by **Zhang et al**(3) observed low to moderate correlations (0.36 <= r <= 0.64). Highest correlation was observed with LAFH (r = 0.64) with its analogous photographic variable. Weak correlation (r = 0.42) was found between FMA' and SN-Go-Me. In contrast, strong correlation was seen between cephalometric and photographic FMA in studies by **Bittner and Pancherz**(14) (r = 0.93)as well as **Gomes LDCR et al**(2) (r = 0.81). Even our study showed a strong correlation (r = 0.933). These differences may be attributed to inclination of SN plane leading to individual variations(15,16).

Staudt and Kiliaridis(8) concluded that several soft tissue measurements significantly represented the underlying sagittal jaw relationships. Analogous photographic and cephalometric ANB angles showed a significant coefficient correlation of r = 0.80. Our study was in agreement with this finding. Strong correlation (r = 0.82) was observed by **Gomes LDCR et al**(2), whereas moderate correlation (r = 0.63) was observed by **Bittner and Pancherz**(14).

Various studies have been carried out to assess the relationship between conventional two dimensional cephalometric variables and three dimensional soft tissue measurements in evaluation of sagittal maxillary and mandibular discrepancy. **Ferrario VF et al**(17) observed a strong correlation (r = 0.77) between soft tissue Wits and cephalometric Wits value. This finding is in sync with our study (r = 0.966).

Both cephalometric and photographic methods were used for assessment of sagittal and vertical changes. Transverse skeletal and soft tissue changes could not be studied by either methods. Also, some measurements were carried out using arbitrary landmarks, increasing the risk of error in landmark identification. This limits our study.

The study suggested that analogous photographic variables had a significant credibility in predicting cephalometric variables with a limited estimate of error. Further studies must be carried out to assess the accuracy of these photographic variables as well as their application in orthodontic diagnosis and treatment planning.

Conclusions

1) Highly significant correlations were observed between analogous photographic and cephalometric values for sagittal as well as vertical variables in all three skeletal patterns.
2) Anteroposterior jaw discrepancy can be analysed with soft tissue photographs more efficiently as compared to vertical discrepancies.
3) Minimal sexual dimorphism might be present in photographic values, however facial proportions are unaffected by it.
4) Photographic method is a reliable, repeatable, cost effective and harmless alternative for orthodontic diagnosis and treatment planning, irrespective of one's gender or skeletal pattern.

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