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Original Article

Skeleto-Dental Features among a Sample of Saudi Female Children Compared to British Standards: A Cephalometric Study

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Abstract

Aim: This cross-sectional observational retrospective study aimed at assessing the cephalometric skeleto-dental features of class I, II, and III skeletal relationship of Saudi female school children sample and comparing the results to the established British Caucasian cephalometric standards. **Materials and Methods:** The sample consisted of 205 retrospective lateral cephalometric radiographs of female school children. The age range of the subjects were between 10 and 13 years old with a mean age of 11 ± 1 years. Several cephalometric and constructed points were identified. Angular, linear, and proportional measurements were obtained and analyzed. The skeleto-dental features of class II and class III were compared to class I of this sample and then compared with the established British Caucasian population. Different angular, linear, and proportional variables were investigated. Descriptive statistics and Student's t-test were used for data analysis. **Results:** The distribution of the skeletal relationship revealed that 68.3% of the sample showed class I relationship, 16.1% class II, and 15.6% class III. The result indicates significant differences among the different classes. A greater tendency towards class II facial pattern and more convex profile among Saudis were detected in the present study compared to Caucasians. Furthermore, The dento-alveolar relationship results showed more bi-maxillary protrusion among Saudi females compared to the British Caucasians. **Conclusion:** The results of the study can serve as a base-line for future investigations in Saudi Arabia. Furthermore, the results obtained can also be of great value in distinguishing the various skeleto-dental features in the different skeletal classes among the Saudi females, and in the clinical diagnosis and treatment planning.

Keywords: *Caucasians, cephalometric, classifications, norms, Saudi female children, skeleto-dental*

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Introduction

Skeletal Discrepancy has a major role in producing malocclusion. A thorough assessment of the skeletal discrepancies in three dimensions, which are anteroposterior, vertical, as well as transverse, are imperative for proper diagnosis and treatment planning. One of the main aims of orthodontic treatment is to improve the facial esthetics. A patient with skeletal discrepancy may require the correction of the skeletal relationships as well as dental occlusion. Thus, in addition to the established information regarding dental malocclusion, an accurate knowledge about the skeletal disharmony is important for the planning and understanding of orthodontic treatment and management.[1-3]

The skeletal relationship has been the subject of interest and concern for many studies. Most of the previous studies of the skeletal relationship have focused on the craniofacial norms of Chinese, Caucasians, and Western Societies.[4-6] In addition, several studies have been

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conducted to establish craniofacial norms of different Arab countries such as Kuwaiti, Yemeni, United Arab Emirates, and Jordanian population.[7-10] In Saudi Arabia, though a number of studies had been carried out to determine the extent of malocclusion and to evaluate the cephalometric measurements of Saudi individuals according to various standards, there is no evidence of published standards for Saudi cephalometric norms, and still orthodontists refer to and apply Caucasian norms when treating Saudi patients.[11-19] The objectives of the present study were to investigate the various types of skeletal classes in a group of female school children in Saudi Arabia, to determine the cephalometric skeleto-dental features of class II and class III skeletal relationship compared to class I, and to compare the results of cephalometric skeleto-dental features of class I for the Saudi sample to the established British Caucasian cephalometric standards.

Materials and Methods

This is a cross-sectional observational study conducted to assess and compare the cephalometric skeleto-dental features of class I, class II, and class III skeletal relationships of Saudi sample to the established British Caucasian cephalometric standards (The research was approved by the IRB ethics committee. The date of approval is 18 June 2020, and renewed on 26 October 2021). The sample in the present study consisted of 205 retrospective lateral skull radiographs of Saudi female school children, which were derived from a large sample (850 radiographs) that was conducted in Jeddah city, Saudi Arabia. The age range of the subjects were between 10 and 13 years old with a mean age of 11 ± 1 years. Lateral skull radiographs were taken with the head in natural head position. The subjects were selected based on the following inclusion criteria:

1. The radiographs should be of high quality.
2. The first permanent molars should be in occlusion.
3. There should be no cleft or craniofacial deformities.
4. There should have been no previous orthodontic treatment.
5. All radiographs utilized in the present study were derived from a single source with a fixed distance between the subject and the source of the x-ray of 6 feet, and the same exposure being made by one machine.

The radiographs were traced under standardized procedures using sharp 3H lead pencil on fine acetate tracing papers. This was performed in a darkened room to obtain maximum contrast and to facilitate landmark identification. Several cephalometric and constructed landmarks were identified and recorded in sequence. Each radiograph with the identified landmarks was digitized by the investigators in a predetermined sequence using digitizer linked to a Mackintosh SE computer. From these coordinated landmarks, horizontal and vertical planes were derived automatically and plotted on the monitor. Furthermore, 18 angular, 17 linear, and 2 proportional measurements were obtained and presented for analysis [Appendix 1]. In the present study, the skeleto-dental features for the Saudi sample, by using the early mentioned angular, linear and proportional measurements [see Appendix 1], were assessed by comparing the values of class II and class III skeletal relationships to class I group, which was considered as a control group, to establish Saudi cephalometric standards and to compare them to the established cephalometric standards reported by Bhatia and Leighton (1993) for British Caucasians.[20]

Statistical analysis

The magnification factor was calculated and found to be 10.6% and was registered into the computer to compensate for enlargement of the linear measurements. In addition, Dahlberg's double determination method error, correlation coefficient, and the Student's t-test were used to determine the intra-examiner reliability of readings, when they were performed by the same examiner 3 weeks later on 30 randomly-selected lateral cephalometric radiographs, and also to determine the inter-examiner reliability, when the same 30 radiographs re-traced and re-digitized by the other investigator within the same week. The inter-examiner and intra-examiner correlations showed significant reliability and minimum method errors of all readings as demonstrated by high coefficient values ranging from 0.97 to 0.99 ($p < 0.001$). G*Power software analysis was used to calculate the statistical power and estimate sample size for the three groups. At significance level (α) equals 0.05 and power 92%, the sample size for each group should be at least 30 subjects to achieve study objectives.[21]

Descriptive statistics were performed among various experimental groups. The Student's t-test was applied for comparison among the control group (class I) and class II and class III skeletal relationship. In addition, the t-test was applied to compare the control Saudi group with British Caucasian norms. In all statistical assessments performed, the level of significance was recognized at 95% level of confidence ($p < 0.05$) to indicate the statistical significance between the studied variables. All statistical analyses were performed using the SPSS software package (Version 22, SPSS Inc., Chicago, IL, USA).

Table 1: The *t*-value and level of significance of different angular and linear measurements for class II, class III skeletal relationship of Saudi females compared to class I in anterioposterior and vertical skeletal relationships

Relationship	Parameter	Classification	Mean	SD	Min.	Max.	*t*	Level of significance
Anterioposterior relationship	ANB angle	Class I Group (*n*=140)	3.1	1.1	0.8	5.3		
		Class II Group (*n*=33)	7.0	1.5	5.5	11.1	13.2	***
		Class III Group (*n*=32)	-0.5	0.9	- 2.9	0.4	16.8	***
	AB plane angle (Fp/AB)	Class I Group (*n*=140)	-4.8	1.8	-0.5	-10.0		
		Class II Group (*n*=33)	-9.8	2.5	-5.5	-7.5	10.3	***
		Class III Group (*n*=32)	0.05	1.3	-3.9	2.7	13.9	***
	Angle of convexity (A-N- Pog)	Class I Group (*n*=140)	5.4	3.1	0.1	13.9		
		Class II Group (*n*=33)	14.5	3.6	8.6	24.5	14.2	***
		Class III Group (*n*=32)	-2.8	2.6	-8.5	3.20	17.2	***
Vertical relationship	SN/MP1 angle	Class I Group (*n*=140)	35.8	5.1	23.7	51.4		
		Class II Group (*n*=33)	37.5	5.8	26.8	51.2	1.6	NS
		Class III Group (*n*=32)	33.6	5.1	18.3	42.7	2.2	*
	SN/Occ angle	Class I Group (*n*=140)	21.7	5.4	8.0	42.0		
		Class II Group (*n*=33)	21.7	5.4	8.0	42.0	0.8	NS
		Class III Group (*n*=32)	19.2	6.2	5.9	35.2	2.3	*
	FH/MP2 angle	Class I Group (*n*=140)	27.7	4.8	15.1	39.5		
		Class II Group (*n*=33)	29.5	5.9	20.3	40.6	1.7	NS
		Class III Group (*n*=32)	26.3	4.8	15.8	35.2	1.5	NS
	FH/Occ angle	Class I Group (*n*=140)	13.5	4.9	4.1	29.9		
		Class II Group (*n*=33)	13.6	5.4	3.7	23.2	0.1	NS
		Class III Group (*n*=32)	11.9	6.3	1.7	26.8	1.3	NS
	Y-Axis angle	Class I Group (*N*=140)	60.0	3.1	50.2	66.6		
		Class II Group (*n*=33)	61.4	3.8	54.1	69.8	2.3	*
		Class III Group (*n*=32)	58.5	3.6	51.6	66.0	2.2	*
	Facial-Axis angle	Class I Group (*n*=140)	92.4	4.0	73	100.5		
		Class II Group (*n*=33)	94.5	2.4	88.3	100	3.5	***
		Class III Group (*n*=32)	89.5	3.3	83.1	96.2	3.8	***
	Gonial Angle	Class I Group (*n*=140)	126.8	6.4	110.9	143.2		
		Class II Group (*n*=33)	127.5	8.3	109.1	142.2	0.45	NS
		Class III Group (*n*=32)	127.9	6.7	113.4	142.9	0.81	NS
	Lower anterior facial height ANS-Me (mm)	Class I Group (*n*=140)	57.2	4.3	47.2	66.9		
		Class II Group (*n*=33)	57.6	4.2	48.9	66.7	0.5	NS
		Class III Group (*n*=32)	56.4	4.4	49.1	68.5	0.08	NS
	Total anterior facial height N-Me (mm)	Class I Group (*n*=140)	103.7	5.6	88.0	115.2		
		Class II Group (*n*=33)	103.5	6.4	92.3	117.5	0.14	NS
		Class III Group (*n*=32)	101.8	5.5	93.8	119.4	1.7	NS
	Posterior facial height (S-Go) (mm)	Class I Group (*n*=140)	65.6	5.0	49.6	79.6		
		Class II Group (*n*=33)	64.1	4.7	54.8	76.5	1.5	NS
		Class III Group (*n*=32)	65.6	5.1	57.0	82.6	0.4	NS
	Ramus Height (mm)	Class I Group (*n*=140)	38.9	3.6	29.4	49.0		
		Class II Group (*n*=33)	37.4	4.0	30.0	49.08	2.0	*
		Class III Group (*n*=32)	39.7	4.3	31.3	49.8	1.1	NS
	ANS-Me/N-Me%	Class I Group (*n*=140)	55.1	2.3	49.6	63.1		
		Class II Group (*n*=33)	55.6	2.1	51.6	60.6	1.1	NS
		Class III Group (*n*=32)	55.4	2.2	50.8	61.1	0.6	NS
	Posterior- anterior facial height ratio (%)	Class I Group (*n*=140)	63.3	4.2	53.5	73.9		
		Class II Group (*n*=33)	62.0	4.7	51.9	71.4	1.5	NS
		Class III Group (*n*=32)	64.5	4.5	57.5	77.4	1.4	NS

$P \leq 0.05$ (*) significant, $P \leq 0.01$ (**) highly significant, $P \leq 0.001$ (***) very highly significant, NS=not significant

Results

The frequency and percentage of skeletal classification of the Saudi females based on ANB angle were presented in Figure 1. It is clear from the results that skeletal class I constitutes the highest percentage (68.3%), whereas skeletal class II and class III exhibited relatively

Table 2: The *t* and level of significance of different cranial base, maxillary, mandibular, and dento-alveolar relationship measurements (angular and linear) for class II and class III compared to class I skeletal relationship of Saudi females

Variables	Parameter	Classification	Mean	SD	Min.	Max.	*t*	Level of significance
Cranial base	Anterior cranial base S-N (mm)	Class I Group (*n*=140)	64.3	2.7	57.5	72.8		
		Class II Group (*n*=33)	64.2	2.4	55.6	69.7	0.2	NS
		Class III Group (*n*=32)	64.9	3.3	59.2	73.3	1.0	NS
	Posterior cranial base S-Ar (mm)	Class I Group (*n*=140)	29.8	2.9	23.3	39.4		
		Class II Group (*n*=33)	29.5	1.8	24.1	34.6	0.8	NS
		Class III Group (*n*=32)	29.8	2.6	25.4	36.5	0.06	NS
	Saddle Angle N-S-Ar	Class I Group (*n*=140)	123.5	5.3	105.2	139.1		
		Class II Group (*n*=33)	123.9	3.6	114.7	131.2	0.38	NS
		Class III Group (*n*=32)	123.3	3.3	113.2	132.4	0.198	NS
Maxilla	SNA angle	Class I Group (*n*=140)	80.8	3.7	71.3	92.3		
		Class II Group (*n*=33)	83.3	2.5	78.2	87.0	3.6	***
		Class III Group (*n*=32)	78.6	4.2	70.1	91.8	2.9	**
	A to Nasion Perpendicular A/N ⊥ FH (mm)	Class I Group (*n*=140)	-1.9	3.2	-10.9	7.5		
		Class II Group (*n*=33)	0.3	2.4	4.7	3.8	4.5	***
		Class III Group (*n*=32)	-3.9	3.6	-11.8	6.4	3.0	**
	Maxillary Length (mm) (Co - A)	Class I Group (*n*=140)	74.9	4.4	50.4	85.5		
		Class II Group (*n*=33)	76.6	2.9	70.8	83.9	2.6	**
		Class III Group (*n*=32)	72.4	5.4	50.0	81.6	2.7	**
Mandible	SNB angle	Class I Group (*n*=140)	77.7	3.5	70.2	89.3		
		Class II Group (*n*=33)	76.3	2.4	72.0	80.5	2.6	**
		Class III Group (*n*=32)	79.2	4.2	70.3	92.7	2.0	*
	Facial angle (FH/ Fp)	Class I Group (*n*=140)	86.4	3.2	79.4	95.6		
		Class II Group (*n*=33)	84.5	3.2	77.9	93.0	3.0	**
		Class III Group (*n*=32)	87.4	3.9	77.9	95.5	0.6	NS
	Pogonion to Nasion ⊥ (mm) (Pog/N ⊥ FH)	Class I Group (*n*=140)	-8.1	6.1	-22.9	12.5		
		Class II Group (*n*=33)	-11.2	4.7	-18.8	-3.3	2.7	**
		Class III Group (*n*=32)	-5.2	6.9	-19.3	15.4	2.3	**
	Pog/NB (mm)	Class I Group (*n*=140)	0.8	1.2	-2.3	4.8		
		Class II Group (*n*=33)	0.1	1.0	-2.1	2.8	2.8	**
		Class III Group (*n*=32)	1.3	1.1	0.7	4.1	1.8	NS
	mandibular body length (Go - Me) (mm)	Class I Group (*n*=140)	60.3	4.1	47.6	70.6		
		Class II Group (*n*=33)	59.2	3.2	54.1	65.3	1.4	NS
		Class III Group (*n*=32)	61.5	3.6	53.7	68.0	0.3	NS
	Mandibular length (mm) (Co - Gn)	Class I Group (*n*=140)	94.4	5.1	80.8	109.6		
		Class II Group (*n*=33)	91.9	4.9	83.6	102.8	2.4	**
		Class III Group (*n*=32)	95.1	5.1	83.0	106.2	0.6	NS
Maxillary incisor position	Upper incisor to NA (mm) (UIE/ NA)	Class I Group (*n*=140)	5.9	2.2	-3.0	11.9		
		Class II Group (*n*=33)	4.0	2.6	-1.8	10.2	4.2	**
		Class III Group (*n*=32)	8.5	2.2	3.6	12.4	4.8	***
	Upper incisor to A ⊥ FH (mm) (UIE/A ⊥ FH)	Class I Group (*n*=140)	4.3	2.3	5.5-	12.0		
		Class II Group (*n*=33)	3.2	2.4	2.0-	9.2	2.2	*
		Class III Group (*n*=32)	5.6	2.4	0.08	11.3	2.9	**
	Upper incisor A-Pog line (mm) (UIE/A-Pog)	Class I Group (*n*=140)	6.9	2.3	-3.2	13.1		
		Class II Group (*n*=33)	8.1	2.5	3.5	13.8	2.4	**
		Class III Group (*n*=32)	6.2	2.2	0.9	10.4	1.6	NS
	Upper incisor- NA angle (UIA-UIE/ NA)	Class I Group (*n*=140)	25.6	5.8	2.6	40.6		
		Class II Group (*n*=33)	22.3	6.8	9.2	36.8	2.8	**
		Class III Group (*n*=32)	32.0	5.0	20.6	43.6	5.6	***

Contd...

Table 2: Contd...

Variables	Parameter	Classification	Mean	SD	Min.	Max.	*t*	Level of significance
Mandibular incisor position	Lower incisor to NB (mm) (LIE/NB)	Class I Group (*n*=140)	6.6	2.0	-0.8	12.0		
		Class II Group (*n*=33)	8.4	2.2	4.2	14.3	4.3	***
		Class III Group (*n*=32)	5.1	2.1	1.6	9.1	3.5	***
	Lower incisor to A-Pog (mm) (LIE/A-Pog)	Class I Group (*n*=140)	3.6	2.2	- 5.8	10.5		
		Class II Group (*n*=33)	3.4	2.4	-0.6	9.2	0.3	NS
		Class III Group (*n*=32)	4.0	2.4	0.08	9.2	0.9	NS
	Lower incisor to NB angle (LIE-LIA/NB)	Class I Group (*n*=140)	30.4	5.5	10.0	43.5		
		Class II Group (*n*=33)	33.4	5.0	25.9	43.4	2.7	**
		Class III Group (*n*=32)	26.0	5.2	17.4	39.1	3.6	***
	Lower incisor to MP_2 angle (LIA-LIE/MP_2)	Class I Group (*n*=140)	97.0	5.9	-10.1	20.5		
		Class II Group (*n*=33)	99.5	5.8	-0.4	21.2	2.2	*
		Class III Group (*n*=32)	93.8	6.2	-9.0	18.2	2.7	**
Maxillary-mandibular incisor relation	Inter-incisal Angle	Class I Group (*n*=140)	120.6	9.1	97.7	163.5		
		Class II Group (*n*=33)	117.2	9.6	96.6	137.2	1.9	*
		Class III Group (*n*=32)	121.9	7.8	102.7	135.0	0.7	NS

P≤0.05 (*) significant, *P*≤0.01 (**) highly significant, *P*≤0.001 (***) very highly significant, NS=not significant. NR=Not recorded

Table 3: Comparison of skeleto-dental characteristics of Saudi females class I skeletal relationship, as a control group, to established mean value of British Caucasian (BC)

Relationship	Parameter	Classification	Mean	SD	*t*	Level of significance
Anterioposterior relationship	ANB angle	Saudi females class I	3.1	1.1	2.2	*
		BC	2.9	2.4		
	AB plane angle (Fp/AB)	Saudi females class I	- 4.8	1.8	4.0	***
		BC	-5.4	3.4		
	Angle of convexity	Saudi females class I	5.4	3.2	0	NS
		BC	5.4	6.1		
Vertical relationship	SN/MP_1 angle	Saudi females class I	35.8	5.1	-	-
		BC	NR	NR		
	SN/Occ angle	Saudi females class I	21.7	5.4	2.66	**
		BC	20.5	4.4		
	FH/MP_2 angle	Saudi females class I	27.7	4.8	6.5	***
		BC	25.1	4.8		
	FH/Occ angle	Saudi females class I	13.5	4.9	9.0	***
		BC	9.8	4.0		
	Y-Axis angle	Saudi females class I	60.0	3.1	11.92	***
		BC	56.9	3.5		
	Facial-axis angle	Saudi females class I	92.4	4.0	9.3	***
		BC	89.3	4.4		
	Gonial Angle	Saudi females class I	126.8	6.4	7.9	***
		BC	131	4.2		
	ANS-Me (mm)	Saudi females class I	57.2	4.3	2.5	*
		BC	58.1	4.5		
	N-Me (mm)	Saudi females class I	103.7	5.6	0.85	NS
		BC	104.1	5.0		
	S-Go (mm)	Saudi females class I	65.6	5.0	0.9	NS
		BC	65.2	4.1		
	Ramus Height (mm)	Saudi females class I	38.9	3.6	0	NS
		BC	38.9	3.1		
	ANS-Me/N-Me%	Saudi females class I	55.1	2.3	12.6	***
		BC	52.7	1.1		
	S-go/N-Me %	Saudi females class I	63.3	4.2	4.28	***
		BC	64.8	4.0		

Table 4: Comparison of different cranial base, maxillary, mandibular, and dento-alveolar relationship measurements (angular and linear) between Saudi females class I skeletal relationship as a control group and established mean value of British Caucasian (BC)

Variables	Parameter	Classification	Mean	SD	*t*	Level of significance
Cranial base	S-N (mm)	Saudi females class I	64.3	2.7	0.43	NS
		BC	64.2	1.9		
	S-Ar (mm)	Saudi females class I	29.8	2.9	2.91	**
		BC	30.5	3.0		
	Saddle Angle	Saudi females class I	123.5	5.3	2.72	**
		BC	124.7	4.4		
Maxilla	SNA angle	Saudi females class I	80.8	3.7	2.87	**
		BC	79.9	3.4		
	A/N ⊥ FH (mm)	Saudi females class I	-1.9	3.2	10.3	***
		BC	0.9	3.0		
	Maxillary length (mm)	Saudi females class I	74.9	4.4	8.91	***
		BC	78.2	3.0		
Mandible	SNB angle	Saudi females class I	77.7	3.5	2.39	*
		BC	77.0	3.4		
	Facial angle (FH/Fp)	Saudi females class I	86.4	3.2	8.51	***
		BC	88.7	3.2		
	Pog/N ⊥ FH (mm)	Saudi females class I	-8.1	6.0	12.6	***
		BC	-1.8	5.6		
	Pog/NB (mm)	Saudi females class I	0.8	1.2	8.0	***
		BC	1.6	1.9		
	mandibular body length (mm)	Saudi females class I	60.3	4.1	8.82	***
		BC	63.3	3.5		
	Mandibular length (mm)	Saudi females class I	94.4	5.1	16.0	***
		BC	101.3	4.2		
Maxillary incisor position	UIE/NA (mm)	Saudi females class I	5.9	2.2	14.1	***
		BC	3.3	1.9		
	UIE/A ⊥ FH (mm)	Saudi females class I	4.3	2.3	18.9	***
		BC	0.7	3.0		
	UIE/A-Pog (mm)	Saudi females class I	6.9	2.3	12.6	***
		BC	4.5	2.0		
	UIA-UIE/NA angle	Saudi females class I	25.6	5.8	7.34	***
		BC	22.0	6.4		
Mandibular incisor position	LIE/NB (mm)	Saudi females class I	6.6	2.0	20.6	***
		BC	3.3	2.4		
	LIE/A-Pog (mm)	Saudi females class I	3.6	2.2	13.9	***
		BC	1.1	2.3		
	LIE-LIA/NB angle	Saudi females class I	30.4	5.5	14.1	***
		BC	23.9	7.5		
	LIA-LIE/MP_2 angle	Saudi females class I	97.0	5.9	-	-
		BC	NR	NR		
Max-mand incisor relation	Inter-incisal Angle	Saudi females class I	120.6	9.1	14.4	***
		BC	131.7	10.5		

$P \leq 0.05$ (*) significant, $P \leq 0.01$ (**) highly significant, $P \leq 0.001$ (***) very highly significant, NS=not significant. NR=Not recorded

similar percentage of 16.1% and 15.6%, respectively. The findings of skeleto-dental characteristics of class II and class III compared to class I skeletal relationship of Saudi females were divided into five sections: Skeletal relationship, cranial base, maxilla, mandible, and dento-alveolar relationship. The results of the analysis of skeletal relationships showed that there were significant differences between class II and class I, and also between class III and class I in anteroposterior skeletal relationships. However, there were no significant differences for most of the comparison in terms of vertical relationships, except for SN/MP_1 SN/occ in class III alone, Y-axis angle and facial axis angle for both class II and class III, and ramus height in class II alone as presented in Table 1. The t-value and level of significance results of the cranial base, maxillary, and mandibular

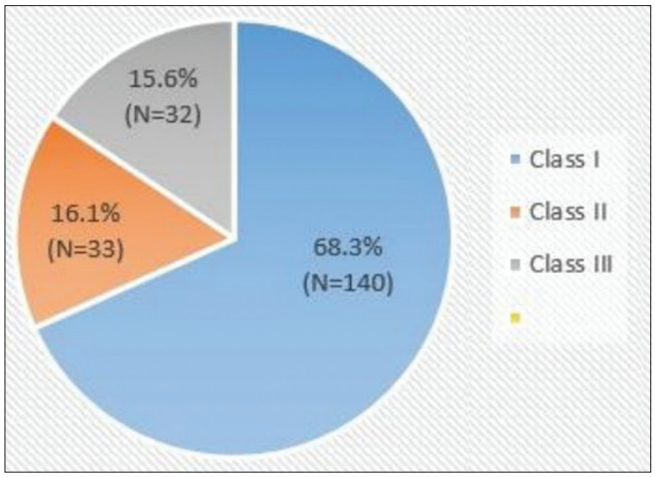

Figure 1: Pie chart of the frequency and percentage of skeletal classification among Saudi female children based on ANB angle

measurements, angular and linear, for class II and class III compared to class I skeletal relationship of Saudi females were presented in Table 2. It is clear that there were no significant differences between all classes in both angular and linear measurements of the cranial base. However, the results of maxillary measurements showed that there were significant differences between skeletal class I, class II, and class III in both angular and linear measurements. The level of significance in class II compared to class I skeletal relationship was very high. Furthermore, the results of the mandibular measurements demonstrated significant differences between skeletal class I and class II skeletal relationship. In contrast, no significant differences were reported with skeletal class III when compared to skeletal class I except in one measurement (pog/N ⊥ FH in mm) that was statistically significant.

With regard to the last variable, the results of dento-alveolar relationship measurements were presented in Table 2 including the maxillary incisor position, mandibular incisor position, and maxillary–mandibular inter-incisal angle. The maxillary incisor position, or skeletal class II angulation was statistically significant when compared to skeletal class I and class III. In addition, mandibular incisor position and angulation showed significant differences between the three skeletal classes except for one linear measurement of lower incisor to A-Pog, when skeletal class II was compared to skeletal class I. Regarding maxillary–mandibular incisor relation, the inter-incisal angle showed statistical significant difference when skeletal class II was compared to skeletal class I. However, no statistical significant difference was observed between skeletal class III and skeletal class I.

The results of the comparison between the skeleto-dental characteristics of Saudi females class I skeletal relationship as a control group and the established norms of British Caucasians were also divided into five sections similar to the previously mentioned variables. Table 3 showed a highly statistical significance between the mean value of Saudi control group compared to the established Briitish Caucasian value results in anteroposterior skeletal relationship as well as in vertical relationship except in the angle of convexity, ramus height, S-Go, and N-Me. The t-value and level of significance results of the cranial base, maxillary, mandibular, and dento-alveolar measurements, angular and linear, for Saudi control group compared to the established British Caucasian values were presented in Table 4. The results showed significant differences with the cranial base measurements except in the linear measurement of S-N. Similarly, the result of the maxillary and mandibular measurement revealed highly statistical significant differences between the Saudi and British sample. Furthermore, the results of the dento-alveolar relationship measurements in terms of maxillary incisor position, mandibular incisor position, and maxillary–mandibular incisor position [Table 4] showed high statistical significant differences, and some degree of bimaxillary proclination for both maxillary and mandibular incisor positions (angular and linear measurements) when the Saudi sample was compared to the established British Caucasian population.

Discussion

Understanding the nature of the skeletal deformity and the identification of the standard features for each racial group is an important aspect in orthodontics; to provide keys for proper diagnosis and the treatment planning of orthodontic patients. Hence, the aims of the present study were to investigate the various types of skeletal classes in a group of female school children in Saudi Arabia, to determine the cephalometric skeleto-dental features of class II and class III skeletal relationship compared to class I, and to compare the cephalometric skeleto-dental results of class I of the Saudi sample to the established British Caucasian cephalometric standards.

The circum pubertal age range (10–13 years old) was selected in this retrospective cephalometric study to ensure proximity of the subjects to the pubertal growth peak when maturational skeletal changes are more intense and noticeable. Also, this circum pubertal age range is the most common age range for individuals to receive their orthodontic treatment because of the appropriateness to perform growth modification therapy and the coincidence with the full eruption of permanent dentition.[22] In this study, only female subjects were included to rule out any gender-dependent variability

in the sample. Some differences in the timing of morphological changes in growth pattern between boys and girls have been reported.[23]

The widely accepted use of the ANB angle as a method for skeletal classification was adopted in this study. The frequency of skeletal discrepancy among the 205 Saudi females was found with higher prevalence of class I (68.3%), followed by class II (16.1%) and class III (15.6%). This finding is consistent with the results of several researchers who conducted randomized clinical trials and concluded that class I malocclusion was the most common type of malocclusion among Saudi population.[19,24,25] In addition, the cases with a class III skeletal relation in the present sudy was larger than that in the Caucasian population, which has a percentage of less than 5%.[26] The facial, skeletal, and dental features for several measurements among Saudi female school children were assessed in the present study. A similar and comparable result was found with another study by Hassan[16] who established cephalometric norms for children living in the western region of Saudi Arabia. In addition to Hassan's measurements, this study measured additional parameters such as AB plane angle, SN/Occ angle, FH/Occ angle, Facial angle, Gonial Angle, Posterior to anterior facial height ratio (%), cranial base measurements, A/N ⊥ FH, Maxillary Length, Pog/NB, mandibular body length, Upper incisor to A ⊥ FH, and Upper incisor A-Pog line. All these additional measurements can be used as a reference in orthodontic treatment of Saudi young female children.

In comparison of the skeleto-dental features of Saudi females to the established British Caucasian population, significant differences were found between Saudis and British Caucasians ($P \leq 0.001$) in anteroposterior relationships except in the angle of convexity that showed insignificant difference. These differences between the two groups can be potentially attributed to sample size and different ethnic background of the subjects. A greater tendency toward class II facial pattern and more convex profile among Saudis were detected in the present study compared to British Caucasians. A similar result was found in another study by Albarakati,[27] and Alshayea *et al*.[28] when the skeleto-dental features of Saudi female children were compared with North American standards. The angular and linear measurements of the various vertical skeletal relationships showed significant differences between class I skeletal relationship of Saudi sample when compared to British Caucasian population except for the total anterior facial height, total posterior facial height, and ramus height. This contradicts the finding of an earlier research that compared the Saudis to the North American standards. It found that with the exception of gonial angle, significant differnences were observed at 0.001% level.[28]

The lower facial height measured from ANS to Me showed a significant difference between Saudi and British Caucasians, which indicates that the Saudi sample has relatively less excessive vertical anterior development. Similar finding was illustrated by Alshayea *et al*.[28] who compared the skeleto-dental features of Saudi female children with North American standards.

Furthermore, the comparison of vertical height proportion also showed highly significant difference between the Saudi and British Caucasian samples. This difference may be due to the variation in the samples. The linear measurements of the cranial base showed no significant differences between the Saudi female and British caucasian for anterior cranial base unlike the North American samples in previous study.[28] However, posterior cranial base and the saddle angle (measured from NS to Ar) revealed significant difference between the Saudi female and the British samples. This could be due to either variation in the samples or landmark identification. Statistical differences were observed in the relative position of maxilla (SNA), mandible (SNB), and short maxillary length when Saudi females were compared to British Caucasian standards. This contradicts the finding of several researchers who found that there was no statistical difference in SNA and SNB between the Saudis and the North American samples, although Saudi showed a greater tendency toward Class II facial pattern.[28,29] Other angular and linear measurements of the mandibular position and size showed significant differences between Saudi and British samples ($P < 0.001$). This finding was consistent with the conclusion of other research.[28]

The dento-alveolar relationship results showed statistically significant differences in all variables studied and more proclined incisors among Saudi females compared to the British Caucasians. This finding was in consistent with studies carried out on other Saudi samples.[12,27-29] When comparing the skeleto-dental characteristic features of the Saudi females to the established means for British and North American Caucasians, it was found that the Saudi female was nearer to the British sample than the North American Caucasian.[28]

Limitations of the study include the relatively small sample size, and the gender limitation to female subjects only. Therefore, further studies are required with a large randomly selected sample of both males and females from different provinces of the Kingdom, with more variables to be studied, e.g., soft tissue and gender effect.

Conclusions

Class I malocclusion was the most common type of malocclusion among Saudi population. However, the cases with a class III skeletal relation was larger than that in the Caucasian population. A greater tendency toward class II facial pattern and more convex profile among Saudis were detected in the present study compared to British Caucasians. Furthermore, the dento-alveolar relationship results showed more bi-maxillary protrusion among Saudi young female children compared to the British Caucasian standards. In addition, Saudi females were nearer to the British sample than the North American Caucasian.

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Conflicts of interest

There are no conflicts of interest.

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Appendix 1: Cephalometric landmarks

Landmarks	Abbreviations	Description
Sella	S	The mid-point of the sella turcica.
Porion	PO	The upper most outermost point on the bony external auditory meatus.
Basion	BA	The most posterior inferior point on the Clivus. It lies on the anterior margin of foramen magnum.
Hinge Axis	HA	The center of the condyle
Pterygoid point	Pt	A point is located on the posterior-superior border of the pterygo-maxillary fissure. It identifies the place of emergence (foramen rotundum) of the maxillary nerve from the cranial base.
Nasion	N	The most anterior point on the fronto-nasal suture.
Orbitale	Or	The most inferior anterior point on the margin of the orbit
Anterior nasal spine	ANS	The tip of the anterior nasal spine
Posterior nasal spine	PNS	The tip of the posterior nasal spine
Point-A	A	The most posterior point on the profile of the maxilla between the anterior nasal spine and alveolar crest
Point-B	B	The most posterior point on the profile of the mandible between the chin point and alveolar crest
Reversal Zone	RZ	It is the reversal zone between two growth fields where the concave surface contour becomes convex.
Pogonion	Pog	The most anterior point on the bony chin.
Menton	Me	The lowest point on the lower border of the mandibular symphysis
Posterior Point 2	PRM2	The most prominent posterior superior point at the angle of the mandible on the ramus
Mandibular base Point-l	MBI	The most inferior point on the lower border of the mandible behind the antigonial notch
Articulare	Ar	The point of intersection between the posterior border of the mandibular condyle and lower border of the cranial base
Upper Incisor edge	UIE	The tip of the most prominent upper incisor crown
Upper Incisor Apex	UIA	The root apex of the most prominent upper incisor
Lower Incisor Edge	LIE	The tip of the most prominent lower incisor crown
Lower Incisor Apex	LIA	The root apex of the most prominent lower incisor
Occlusal Point	Oc	The mid-point in the occlusal space between the upper and lower first premolars
Upper Molar Distal Contact Point	UDC	The posterior contact (height of contour) of the maxillary first molar
Lower Molar Distal Contact Point	LDC	The posterior contact point of the mandibular first molar
Upper Molar Distal Root	UDR	Distal buccal root of the maxillary first molar
Lower Molar Distal Root	LDR	Distal root of the mandibular first molar

Constructed landmarks

Landmarks	Abbreviations	Description
Gnathion	Gn	The most anterior inferior point on the mandibular symphysis.
Gonion	Go	The most posterior inferior point on the angle of the mandible.
Condylion	Co	The most superior posterior point of the mandibular condyle.

The Horizontal Plane

Planes	Abbreviations	Description
Sella-Nasion plane	SN	A plane joining sella to nasion and represented by the anterior cranial base
Frankfort Horizontal	FH	This plane passes through points porion and orbitale
Occlusal Plane	Occ	A plane passes through the occlusion of the premolars or deciduous molars and first and permanent molars
Mandibular Plane	MP	It is defined by two ways: A plane joining gonion to menton and a plane joining gonion to gnathion

The Vertical Planes

Planes	Abbreviations	Description
The Facial Plane	Fp	A plane joining the nasion to pogonion and used to assess the facial profile
Y-Axis Plane	Y-axis	A plane joining sella to gnathion
Facial Axis plane	F-axis	A plane joining pterygoid (Ptm) and gnathion (Gn).
Ramal Plane	Rm	A plane joining Articulare (Ar) and Gonion (Go).
A-B Plane	A-B	A plane joining A point to B point

Angular Measurements

Angles	Abbreviations	Description
SNA angle	SNA	The angle subtended by the SN plane and point A.
SNB angle	SNB	The angle subtended by SN plane and point B.
ANB angle	ANB	The difference between angles SNA and SNB.
Angle of convexity	A-N- Pog	The angle subtended between facial plane and the line joining points A and N.
Facial angle	FH/Fp	The inferior inside angle subtended by the Facial plane and Frankfort plane.
AB plane angle	Fp/AB	The angle subtended by the line joining points A and B and the facial plane.
Saddle angle	N-S-Ar	The angle subtended by the SN plane and the line joining sella to articulare.
Gonial angle	Ar-Go-Me	The angle subtended by the Ramal plane and mandibular plane.
SN-occlusal plane angle	SN/Occ	The angle subtended by the SN plane and occlusal plane.
SN-mandibular plane angle	SN/MP_1	The angle subtended by the SN plane and mandibular plane (Go-Gn).
Frankfort-occlusal plane angle	FH/Occ	The angle subtended by the Frankfort plane and occlusal plane.
Frankfort-mandibular plane angle	FH/MP_2	The angle subtended by the Frankfort plane and mandibular plane (Go-Me)
Y-Axis angle	FH/Y-Axis	The angle subtended by the Frankfort plane and Y-axis plane.
Facial-Axis angle	F-Axis/NBa	The angle subtended by the F- Axis plane and the line joining points N and Ba.
Lower incisor to MP_2 angle	LIA-LIE/MP_2	The angle between the long axis of the lower incisor and the mandibular plane (Go-Me)
Upper incisor to NA angle	UIA-UIE/NA	The acute angle formed by the long axis of the upper incisor and the line N A.
Lower incisor to NB angle	LIE- LIA/NB	The acute angle formed by the long axis of the upper and lower incisors.
Interincisal angle	LIE-LIA/UIE-UIA	The angle formed by the long axes of the upper and lower incisors

Linear Measurements

Linear Measurements	Abbreviations	Description
Point A to Nasion Perpendicular	A/N ⊥ FH	The horizontal distance in mm from point A to the vertical line extended inferiorly from Nasion perpendicular to the Frankfort plane.
Pogonion to Nasion Perpendicular	Pog/N ⊥ FH	The horizontal distance in mm from Pogonion to the vertical line extended inferiorly from nasion perpendicular to the Frankfort plane.
Maxillary length	Co - A	The horizontal distance in mm from condylion to point A.
Mandibular length	Co - Gn	The distance in mm from condylion to Gnathion.
Mandibular body length	Go - Me	A horizontal distance in mm from Gonion to Menton.
Pog to N-B points.	Pog/NB	The horizontal distance in mm from Pog to line joining N, B points.
Anterior cranial base	N - S	The horizontal distance in mm from Nasion to Sella.
Posterior cranial base	S - Ar	The distance in mm from Sella to Articulare.
Ramus height	Ar - Go	The distance in mm from Articulare to Gonion.
Posterior facial height	S - Go	The distance in mm from Sella to Gonion.
Total anterior facial height	N - Me	The distance in mm from Nasion to Menton.
Lower anterior facial height	ANS - Me	The distance in mm from Anterior nasal spine to Menton.
Upper incisor to NA	UIE/NA	The horizontal distance in mm from the tip of the upper to the NA line.
Lower incisor to NB	LIE/NB	The horizontal distance in mm from the tip of the lower incisor to the line NB.
Upper incisor A-Pog line	UIE/A Pog	The horizontal distance in mm from the tip of the upper incisor to the line A-pog.
Upper incisor to A ⊥ FH	UIE/A ⊥ FH	The horizontal distance in mm from facial surface of the upper incisor to the vertical line passing through point A parallel to Nasion perpendicular to the Frankfort plane.
Lower incisor to A-Pog	LIE/A Pog	The horizontal distance in mm from facial surface of the lower incisor to the line A-Pog.

Proportional measurements

Proportional measurements	Abbreviations	Description
Posterior-anterior Facial height (%)	S - Go/N - Me	The posterior facial height as a percentage of total anterior facial height.
Lower anterior facial height (%)	ANS - Me/N -Me	The lower anterior facial height as a percentage of total anterior facial height.