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Original Article

Transverse dentofacial dimensions according to skeletal maturation

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Abstract

Aim: This study aimed to determine the dentofacial transverse dimensions according to the hand-wrist and cervical vertebrae skeletal maturation stages in order to evaluate the differences between the sexes, to identify the correlations between transverse measurements, and to compare the transverse measurements of individuals of different origins with those of Turkish individuals.

Methodology: Transverse measurements were performed using the posteroanterior radiographs of 265 Turkish individuals (150 females, 115 males) at 7–17 years of age. Skeletal maturation was evaluated using hand-wrist radiographs and lateral cephalometric radiographs, and the results were used to categorize the patients into 3 stages of hand-wrist skeletal maturity (prepubertal/pubertal/postpubertal) and 2 stages of cervical vertebrae maturity (prespurt/postspurt). Seven measurements were evaluated. A multivariate linear regression model was used to evaluate the correlations between transverse measurements and the variables of skeletal age and sex.

Results: Sex was a significant explanatory factor for all transverse variables. In the postpubertal and postspurt stages, all transverse measurement values were found to be higher in males. Postpubertal term was a significant explanatory factor for maxillary, mandibular, mandibular intermolar, and maxillary intermolar widths, whereas pubertal term was only a significant explanatory factor for maxillary intermolar width.

Conclusion: Skeletal age and sex should be taken into account when determining transverse dentofacial measurements.

Keywords: transverse, radiographs, maturation, hand-wrist, cervical vertebrae

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Introduction

It is indisputable that cephalometric radiographs are of great importance in assessing the craniofacial complex, evaluating morphology and growth, diagnosing anomalies, planning treatment, and assessing growth outcomes and treatment effects. However, lateral cephalometric x-rays provide information about skeletal, dental, and soft tissue morphology and relationships in the sagittal dimensions, whereas they do not provide information about skeletal and dentoalveolar relationships in the transverse dimensions; thus, posteroanterior cephalometric x-rays are used for this purpose (1). These radiographs provide the opportunity to evaluate the width and angular relationships of dental arches with bone bases, the relationships of bilateral osseous and dental structures in vertical dimensions, the widths and transverse positions of the maxilla and mandible, the width of the nasal cavity, and vertical and transverse facial asymmetries (2).

Estimation and evaluation of craniofacial growth are of great importance for orthodontic treatment. The dental and skeletal structures and soft tissues of adolescents, the largest patient group in orthodontics, continue growing during the treatment period (3). Treatment timing plays an important role in the results of almost all dentofacial orthopedic treatments for dental-skeletal system conflicts in growing patients. (4). Numerous studies have evaluated transverse dimensions according to chronological age (5–11), but it is more accurate to evaluate the biological or physiological maturation because of significant developmental differences among individuals of the same chronological age. One of the most important methods for assessing biological maturation is radiological evaluation (12, 13), and hand-wrist radiographs and lateral cephalograms are the most commonly used types (14).

This study aimed to determine the dentofacial transverse dimensions according to the hand-wrist and cervical vertebrae maturation stages, to evaluate the differences between the sexes, to identify the correlations between the transverse measurements, and to compare the transverse measurements of individuals of different origins with those of Turkish individuals.

Materials and Methods

Patients admitted to the Department of Orthodontics at the Kırıkkale University, Faculty of Dentistry between 2012 and 2017 for orthodontic treatment who underwent posteroanterior, lateral cephalometric, and hand-wrist radiographs for diagnostic purposes were evaluated in this study. This cross-sectional and retrospective study was approved by the Kırıkkale University, Clinical Research Ethics Committee (Decision No. 2018/16-2).

The following patients were included in the study: patients with a skeletal and dental class I relationship (an ANB angle between 0 and 4 degrees); without systemic disorder, skeletal asymmetry, or posterior cross-bite; with minimal crowding (less than 3 mm); no diastema; no previous orthodontic treatment; no systemic disorder adversely affecting bone development; no developmental retardation; no congenital or acquired malformation in the hand-wrist, jaw, face, or cervical vertebrae; and radiographs without artifacts or distortions that could prevent the evaluation. A total of 265 individuals (150 females, 115 males) 7–17 years of age were included in the study. All these patients were Turkish in origin.

The posteroanterior radiographs were acquired using a Kodak 9000 digital panoramic unit (Carestream Health, Rochester, NY, USA). The radiographs were taken under standard conditions (e.g., in terms of the distance between the radiograph and the porionic axis and the source of radiation). Images were obtained with the horizontal plane of Frankfurt parallel to the ground, teeth with maximum intercuspation, and lips in a resting position. All radiographs were taken with the same device by the same operator. The posteroanterior radiographs were analyzed using Dolphin Software (Dolphin Imaging 11.8 Premium, Chatsworth, CA). All measurements were defined as follows (Fig. 1):

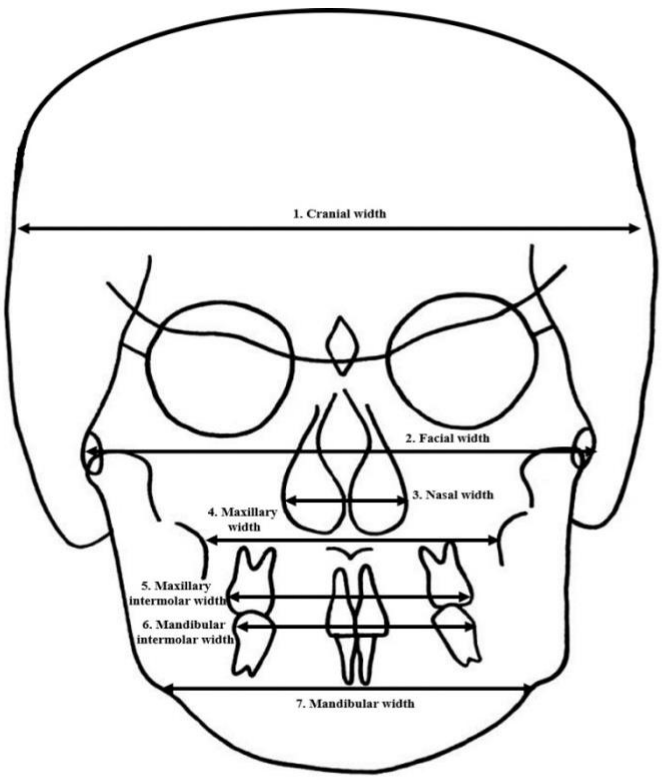

Figure 1. **Transverse measurements.**

1. Cranial width: the width between the most lateral points on the cranium.
2. Facial width: the width between the most lateral points on the zygomatic arch.
3. Nasal width: the width between the most lateral points on the nasal cavity.
4. Maxillary width: the width between the jugal process (i.e., the intersection of the outline of the maxillary tuberosity) and the zygomatic buttress.
5. Maxillary intermolar width: the width between the most lateral points on the buccal surfaces of the maxillary first molar crowns.

6. Mandibular intermolar width: the width between the most lateral points on the buccal surfaces of the mandibular first molar crowns.
7. Mandibular width: the width between the antegonial notches.
8. Maxillomandibular width ratio: maxillary width divided by mandibular width.
9. Maxillomandibular width difference: maxillary width subtracted from mandibular width.

Hand-wrist and lateral cephalometric radiographs were used to evaluate skeletal maturation. The growth and development periods of the wrist radiographs were evaluated according to the methods developed by Björk (15) and Grave and Brown (14). Patients were categorized into 3 groups:

Group 1: Prepubertal: Stage 1, Stage 2, Stage 3 (n=55)
Group 2: Pubertal: Stage 4, Stage 5, Stage 6 (n=88)
Group 3: Postpubertal: Stage 7, Stage 8, Stage 9 (n=122).

Cervical vertebrae maturation was evaluated using the method developed by Hassel and Farman (16). Patients were categorized into 2 groups:

Group 1: Prespurt: Stage 1, Stage 2, Stage 3 (n=90)
Group 2: Postspurt: Stage 4, Stage 5, Stage 6 (n=175).

Measurements were carried out by 2 experienced observers (TSE and FNU). To determine the accuracy and reliability of the cephalograms, 50 radiographs were re-evaluated blindly 4 weeks following the measurements by the same observers.

Statistical analysis

The mean, standard deviation, median, minimum, and maximum values were used in descriptive statistics for continuous data, and percentage values were used for discrete data. The Shapiro–Wilk test was used as a test of normality. The Pearson correlation coefficient was used to analyze the relationship between transverse measurements.

A multivariate linear regression model was used to investigate which variables were effective in explaining transverse measurements.

Intra-examiner and inter-examiner reliability were determined using the intraclass correlation coefficient. IBM SPSS version 20 was used for the analyses, and p values <0.05 were considered to represent statistical significance.

Results

The intra-/inter-examiner correlation coefficient indicated a high degree of reliability between the 2 observers' measurements (inter-examiner r=0.85<x<1.00; intra-examiner r=0.88<x<1.00). In the multiple linear regression analysis, in the presence of 3 independent variables, when the type-1 error rate was taken as 0.05, the observed statistical power for $R2=0.176$ calculated from the multiple regression equation was calculated as 0.99.

The mean age of the 265 patients included in our study was 13.04±2.36 years. Of the patients, 56.6% were female and 43.4% were male. Table 1 shows the number of individuals and the mean age for the skeletal maturation stages by sex.

Table 1. Mean age and number of children for each skeletal maturation of cervical vertebrae and hand-wrist.

	Female		Male	
Hand-wrist phases	n	Age (year)	n	Age (year)
1	4	8.00±0.82	19	9.63±1.16
2	6	9.83±0.98	11	11.55±1.51
3	5	10.20±1.64	10	11.80±0.92
4	14	10.79±1.22	18	12.61±0.85
5	29	11.41±1.05	17	13.35±1.27
6	7	12.29±0.76	3	14.67±0.58
7	10	12.80±0.79	6	15.17±0.75
8	37	14.35±1.25	19	14.79±1.18
9	38	15.68±1.19	12	16.00±1.04
Total	**150**	**13.10±2.41**	**115**	**12.96±2.29**
Hand-wrist stages				
Prepubertal	15	9.47±1.46	40	10.70±1.57
Pubertal	50	11.36±1.12	38	13.11±1.18
Postpubertal	85	14.76±1.51	37	15.24±1.19
Cervical vertebrae phases				
1	3	8.33±0.58	17	9.65±1.22
2	11	9.73±1.49	15	11.13±1.12
3	18	10.83±1.10	26	12.54±0.99
4	44	12.07±1.35	20	13.50±1.50
5	37	14.32±1.49	23	14.65±1.03
6	37	15.59±1.14	14	16.14±0.86
Total	**150**	**13.10±2.41**	**115**	**12.96±2.29**
Cervical vertebrae stages				
Prespurt	32	10.22±1.43	58	11.13±1.64
Postspurt	118	13.88±1.99	57	14.61±1.54

Transverse measurements and comparisons of the hand-wrist and cervical vertebrae maturation of females and males are shown in Table 2.

The results of multiple regression analyses with explanatory variables (sex, hand-wrist and cervical vertebrae maturation stages) for each transverse measurement are presented in Table 3.

Postpubertal stage and sex were statistically significant explanatory factors for maxillary width (R^2=0.142, F=10.725 p=0.000, adjusted R^2=0.128). Maxillary width increased by 2.270 mm from the prepubertal to the postpubertal stage of hand-wrist maturation (p<0.05). Female sex was associated with a decrease of 3.576 mm in maxillary width compared to male sex (p<0.001) (Table 3).

Postpubertal stage and sex were statistically significant explanatory factors for mandibular width (R^2=0.160, F=12.410 p=0.000, adjusted R^2=0.147). Mandibular width increased by 4.227 mm from the prepubertal stage to the postpubertal stage of hand-wrist maturation (p<0.01). Female sex was associated with a decrease of 4.777 mm in mandibular width compared to male sex (p <0.001) (Table 3).

Correlations between all transverse measurements of male and female subjects were statistically significant (p<0.001) (Table 4).

Table 5a and 5b show the transverse measurements obtained during this study and compares them to those obtained in other studies examining the Turkish population (2, 6, 8–11, 17–19).

Table 2. Descriptive statistics and comparison of transversal measurements according to the hand-wrist maturation and cervical vertebrae maturation of females and males.

		Prepubertal[α]		Pubertal[α]		Postpubertal[α]		Prespurt[β]		Postspurt[β]	
		Mean± SD	p	Mean± SD	p	Mean± SD	p	Mean± SD	p	Mean± SD	p
Nasal w.	Kız	25.87±2.42	0.142	26.03±2.69	0.052	27.24±2.57	0.019	25.97±2.37	0.067	26.90±2.71	0.009
	Erkek	27.11±2.85		27.28±3.25		28.57±3.34		27.14±3.10		28.14±3.22	
Maxillary w.	Kız	57.03±2.95	0.031	57.88±4.20	0.001	58.55±3.79	0.003	57.83±3.64	0.026	58.27±3.93	0.000
	Erkek	59.59±4.09		61.29±5.08		62.67±4.93		59.90±4.41		62.41±4.96	
Mandibular w.	Kız	71.37±5.41	0.038	72.69±6.07	0.003	75.07±4.78	0.000	72.65±6.22	0.082	74.25±5.19	0.000
	Erkek	74.86±5.43		77.14±7.74		80.59±6.36		75.06±6.25		79.89±6.76	
Mn-intermolar w.	Kız	53.95±4.93	0.601	54.29±4.10	0.005	55.39±4.23	0.000	54.45±4.56	0.404	55.00±4.20	0.000
	Erkek	54.75±5.04		57.09±4.92		59.40±5.36		55.34±4.93		58.73±5.37	
Cranial w.	Kız	136.95±8.71	0.173	133.72±9.03	0.003	133.47±6.96	0.000	136.71±9.45	0.119	133.14±7.28	0.000
	Erkek	140.91±9.73		139.92±9.71		142.00±9.54		140.07±9.82		141.82±9.42	
Facial w.	Kız	108.60±6.78	0.095	108.26±7.98	0.039	109.56±6.51	0.000	109.56±7.97	0.188	108.89±6.79	0.000
	Erkek	112.72±8.42		111.92±8.31		116.05±8.07		111.95±8.27		115.14±8.28	
Mx-intermolar w.	Kız	51.74±4.19	0.202	52.67±4.16	0.001	54.23±3.76	0.000	52.63±4.04	0.153	53.69±4.00	0.000
	Erkek	53.54±4.74		56.07±5.17		58.68±5.18		54.04±4.67		58.05±5.41	
Mx-Mn w. dif.	Kız	14.35±4.13	0.458	14.80±4.32	0.287	16.52±3.35	0.043	14.82±4.37	0.724	15.98±3.69	0.015
	Erkek	15.27±4.07		15.85±4.76		17.92±3.69		15.16±4.32		17.49±4.01	
Mx- Mn w. ratio	Kız	80.13±4.56	0.781	79.84±4.80	0.904	78.07±3.75	0.760	79.86±4.57	0.887	78.60±4.17	0.581
	Erkek	79.75±4.50		79.71±4.81		77.85±3.72		80.01±4.64		78.23±4.05	

Table 3. Multiple regression analysis results with explanatory variables for transversal measurements.

	Parameter	Estimate(B)	95 % CI		t	p value
Nasal w.	Intercept	27.124	26.342	27.906	68.325	0.000
	Hand-wrist stages					
	Pubertal	0.153	-1.036	1.343	0.254	0.800
	Post pubertal	1.380	-0.114	0.284	1.819	0.070
	Cervical v. stages					
	Postspurt	0.036	-1.156	1.229	0.060	0.952
	Gender (female)	-1.284	-2.020	-0.547	-3.430	0.001
Maxillary w.	Intercept	59.865	58.698	61.033	100.979	0.000
	Hand-wrist stages					
	Pubertal	1.432	-0.344	3.209	1.587	0.114
	Post pubertal	2.270	0.038	4.501	2.003	0.046
	Cervical v. Stages					
	Postspurt	0.154	-1.627	1.935	0.170	0.865
	Gender (female)	-3.576	-4.677	-2.476	-6.399	0.000
Mandibular w.	Intercept	75.204	73.589	76.818	91.713	0.000
	Hand-wrist stages					
	Pubertal	1.745	-0.713	4.202	1.398	0.163
	Post pubertal	4.227	1.141	7.313	2.697	0.007
	Cervical v. Stages					
	Postspurt	0.642	-1.822	3.105	0.513	0.609
	Gender (female)	-4.777	-6.299	-3.254	-6.179	0.000
Mn-intermolar w.	Intercept	55.342	54.059	56.624	84.978	0.000
	Hand-wrist stages					
	Pubertal	1.841	-0.111	3.792	1.857	0.064
	Post pubertal	3.327	0.876	5.778	2.673	0.008
	Cervical v. Stages					
	Postspurt	0.005	-1.952	1.961	0.005	0.996
	Gender (female)	-2.960	-4.169	-1.751	-4.820	0.000
Cranial w.	Intercept	141.692	139.298	144.086	116.540	0.000
	Hand-wrist stages					
	Pubertal	-1.031	-4.675	2.613	-0.557	0.578
	Post pubertal	-0.211	-4.787	4.364	-0.091	0.928
	Cervical v. Stages					
	Postspurt	-0.702	-4.355	2.950	-0.379	0.705
	Gender (female)	-6.772	-9.029	-4.515	-5.908	0.000
Facial w.	Intercept	112.964	110.870	115.057	106.260	0.000
	Hand-wrist stages					
	Pubertal	-0.221	-3.407	2.965	-0.137	0.891
	Post pubertal	2.157	-1.844	6.159	1.062	0.289
	Cervical v. Stages					
	Postspurt	-0.110	-3.303	3.084	-0.068	0.946
	Gender (female)	-4.993	-6.966	-3.019	-4.982	0.000
	Intercept	54.021	52.796	55.245	86.860	0.000

Mx-intermolar w.	Hand-wrist stages					
	Pubertal	1.987	0.123	3.851	2.100	0.037
	Post pubertal	3.771	1.430	6.112	3.172	0.002
	Cervical v. Stages					
	Postspurt	0.284	-1.584	2.152	0.299	0.765
	Gender (female)	-3.581	-4.736	-2.427	-6.108	0.000
Mx-Mn w. dif.	Intercept	15.339	14.252	16.425	27.805	0.000
	Hand-wrist stages					
	Pubertal	0.312	-1.341	1.966	0.372	0.710
	Post pubertal	1.957	-0.119	4.033	1.856	0.065
	Cervical v. Stages					
	Postspurt	0.487	-1.170	2.145	0.579	0.563
	Gender (female)	-1.200	-2.225	-0.176	-2.308	0.022
Mx-Mn w. ratio	Intercept	15.339	14.252	16.425	27.805	0.000
	Hand-wrist stages					
	Pubertal	0.312	-1.341	1.966	0.372	0.710
	Post pubertal	1.957	-0.119	4.033	1.856	0.563
	Cervical v. Stages					
	Postspurt	0.487	-1.170	2.145	0.579	0.563
	Gender (female)	-1.200	-2.225	-0.176	-2.308	0.022

Table 4. Correlation between all transversal measurements of females and males.

	Female		Male	
	r	p	r	p
Nasal w.- Maxillary w.	0.532	0.000	0.674	0.000
Nasal w.- Mandibular w.	0.580	0.000	0.655	0.000
Nasal w.- Mn-intermolar w.	0.536	0.000	0.616	0.000
Nasal w.- Cranial w.	0.513	0.000	0.615	0.000
Nasal w.- Facial w.	0.523	0.000	0.502	0.000
Nasal w.- Mx-intermolar w.	0.567	0.000	0.663	0.000
Maxillary w.- Mandibular w.	0.706	0.000	0.787	0.000
Maxillary w.- Mn-intermolar w.	0.723	0.000	0.770	0.000
Maxillary w.- Cranial w.	0.556	0.000	0.697	0.000
Maxillary w.- Facial w.	0.604	0.000	0.673	0.000
Maxillary w.- Mx-intermolar w.	0.829	0.000	0.841	0.000
Mandibular w.- Mand-İntermolar w.	0.699	0.000	0.786	0.000
Mandibular w.- Cranial w.	0.556	0.000	0.683	0.000
Mandibular w.- Facial w.	0.651	0.000	0.690	0.000
Mandibular w.- Mx-intermolar w.	0.762	0.000	0.840	0.000
Mn-intermolar w.- Cranial w.	0.564	0.000	0.637	0.000
Mn-intermolar w.- Facial w.	0.552	0.000	0.612	0.000
Mn-intermolar w.- Mx-intermolar w.	0.815	0.000	0.865	0.000
Cranial w.- Facial w.	0.825	0.000	0.778	0.000
Cranial w.- Mx-intermolar w.	0.567	0.000	0.696	0.000
Facial w.- Mx-intermolar w.	0.604	0.000	0.693	0.000

Table 5a. Published transversal measurements of individuals from other populations.

Measurements	Korean mea. (n=577)				Ricketts mea. (n=NA)	Chinese mea. (n=547)				Kuwaiti mea. (n= 159)
	First stage*		Final stage*		9 years	7.5-11.5 years		12.5-17.5 years		13-14 years
	Female	Male	Female	Male		Female	Male	Female	Male	
	Mean±SD		Mean±SD		Mean±SD	Mean±SD		Mean±SD		Mean±SD
Nasal w.	26.43±2.16	28.24±1.89	31.28±1.98	33.10±2.50	25±NA	28.06±2.8	29.6±3.3	31.4±2.4	32.9±2.8	29±2.85
Maxillary w.	63.53±2.61	67.54±3.07	67.43±2.94	73.58±2.76	61.9±NA	65±3.4	67±3.4	67.2±3	71±3.9	62.7±4.88
Mandibular w.	80.68±3.76	86.90±3.73	91.14±3.28	95.75±4.88	76.1±NA	81.6±4.3	82.4±3.4	85.2±3.9	89±3.7	82.4±5.39
Mn-intermolar w.	59.14±1.35	60.15±2.40	56.26±2.40	59.91±3.24	50.1±NA					52±2.66
Cranial w.	155.12±5.68	160.52±7.49	155.24±5.69	164.23±8.78		147.9±5.1	150.7±5.1	148.9±5	155.3±5.3	
Facial w.	125.28±4.15	131.78±4.54	136.77±3.73	147.80±4.09	115.7±NA	119.2±7.5		127.6±5.5	133.5±7.7	125.8±7.43
Mx-intermolar w.	58.44±1.73	61.38±2.68	59.21±2.48	62.77±3.29	52.9±NA					54.1±2.74
Mx-Mn w. dif.	17.15±3.11	19.37±2.98	23.70±3.85	22.16±4.99						19.7±4.72
Mx-Mn w. ratio	78.83%±3.13	77.77%±2.98	74.06%±3.66	77.01%±4.32		79.7%±3.2	81.4%±4.2	79%±3.9	79.8%±4.9	

*, according to hand-wrist maturation; mea., measurements; w., width; dif., difference; Mx., maxillary; Mn., mandibular.

Table 5b. Continued

Measurements	Austrian mea. (n=588)		Pakistani mea. (n=100)	Irish mea. (n=18)				Japanese mea. (n=50)	American mea. (n=50)			
	6 years	15 years	18-35 years	7 years		15 years		8 years	6 years		18 years	
				Female	Male	Female	Male		Female	Male	Female	Male
	Mean±SD		Mean±SD	Mean±SD		Mean±SD		Mean±SD	Mean±SD		Mean±SD	
Nasal w.	25.36±1.79	30.10±2.38	34.11±5.02	26.29±1.60	27.48±2.78	30.50±1.55	34.37±2.60	26±NA	22.88±1.66	22.93±1.92	28.64±2.49	30.48±2.07
Maxillary w.	60.99±4.39	67.37±2.87	71.41±5.80	52.93±2.10	55.14±1.63	58.46±2.84	63.75±2.46	65±NA	54.44±1.86	56.12±2.34	61.8±2.97	66.24±3.12
Mandibular w.	78.5±6.86	91.19±3.59	103.19±13.53	80.48±3.81	80.50±3.01	91.54±3.17	94.64±4.63	85.8±NA	76.33±2.77	78.43±4.42	92.17±3.96	99.36±5.17
Mn-intermolar w.	58.36±4.72	58.36±2.86		45.15±2.35	47.07±2.09	45.99±1.74	49.16±2.51		54.10±2.17	56±2.96	53.72±1.55	56.12±2.17
Cranial w.				135.71±5.45	139.17±4.59	139.17±5.52	143.25±4.66		139.23±4.11	142.88±6.55	144.42±5.02	150.90±7.07
Facial w.			141.14±6.81	109.43±3.22	110.97±4	122.88±3.59	128.11±4.47	129.5±NA	108.22±3.27	110.82±3.45	126.03±5.68	134.06±4.80
Mx-intermolar w.	56.11±4.58	60.23±2.63		44.73±1.52	46.84±2.08	46.11±1.62	49.28±2.61		53.67±2.58	53.18±2.66	55.67±151	59.46±2.71
Mx-Mn w. dif.												
Mx-Mn w. ratio	77%±3.3	74%±3.5										

*, according to hand-wrist maturation; mea., measurements; w., width; dif., difference; Mx., maxillary; Mn., mandibular.

Discussion

In orthodontic and orthopedic treatments, the timing of treatment is as critical as the treatment protocol. Initiating the treatment in the appropriate maturation period is crucial for the growth of the craniofacial region and provides the best treatment results (4,19). Individual variations may be encountered when children are evaluated according to their chronological age. Thus, the evaluation of transversal measurements according to skeletal maturation stages might be beneficial in providing appropriate treatment and ensuring the best timing (19).

In various populations, including American, Chinese, Kuwaiti, Austrian, Pakistani, Northern Irish, Japanese, and Korean populations, transversal measurements have been evaluated according to chronological age (2,5–11,17,18). Hwang et al. identified skeletal maturation using hand-wrist radiographs and transversal values in a Korean population (19). In our study, transversal measurement values were determined according to the cervical vertebra and hand-wrist maturation stages of growing Turkish individuals, and these measurements were compared with those of other populations.

Hand-wrist radiography is often used to determine skeletal maturation due to the presence of various bones in this region. In our study, the methods established by Björk (15) and Grave and Brown (14) were used, and the mean age at each skeletal maturation stage was close to those in our study; a one-year age difference was observed in Turkish individuals at each stage.

The evaluation of cervical vertebra maturation is another method for evaluating skeletal maturity. Examining the morphological characteristics of the second, third, and fourth cervical vertebrae is an effective method for estimating growth phase (4,16). The cervical vertebral maturation method (4) was preferred in our study because of its accuracy and reproducibility.

Nasal width. Nasal width is very important for orthodontic patients, as normal nasal breathing is provided when it is sufficiently wide (2). The fact that the width of the nasal cavity can be changed with orthopedic treatments such as extraoral traction or maxillary expansion is of great interest to orthodontists (2,20). Ricketts (2) found that nasal width was 25 mm at age 9 and increased by 0.5 mm per year with growth. Snodell et al. (11) reported that the increase ranged from 24.6 mm in females to 24.7 mm in males, and between 0.2 mm and 1.4 mm per year. In our study, we found an increase of 1.38 mm from the prepubertal stage to the postpubertal stage. In addition, studies have found that nasal dilatation was higher in men than in women, supporting our study (6,10,11,19).

Nasal width and maxillary width are correlated in both sexes. This correlation confirms the positive correlation between airway and maxillary width (21, 22).

Maxillary width. Savara and Singh found that incremental growth rates decreased between 6 and 13 years of age, but had a distinct peak between 14 and 15 years of age (23). Similarly, Snodell et al. observed a decrease in the growth rate between the ages of 6 and14 and an acceleration at the age of 15 (11). In our study, the 1.43 mm growth from the prepubertal stage to the pubertal stage was not found to be significant in the transversal development of the maxilla, but the 2.27 mm of growth from the prepubertal to the postpubertal period was significant. Compared to other studies (23), this result supports a decrease in the growth rate from prepuberty to puberty and a significant increase in the growth rate from puberty to postpuberty. Also, the Turkish population was observed to have similar values as the Irish population (10) in terms of maxillary width.

Mandibular width. Hwang et al. (19) found the mandibular width in the first stage of skeletal maturation to be 86.90 mm in men and 80.68 mm in women; in the fourth, fifth and sixth stages, 90 mm in men, 86 mm in women; and in the last stage, 95.75 mm in men and 91.14 mm in women. These values are considerably higher than those in our study. We found that females had a mandibular width of 75.07 mm and males 80.59 mm even in the postpubertal stage. Previous studies have found the mandibular width of Turkish subjects to be smaller when compared to that of other populations (2,6,8–11,18,19,24). In addition, in our study, the mandibular width increased by 4.22 mm from the prepubertal period to the postpubertal period. Ricketts (2) stated that the mandibular width, which he found to be 76.1 mm at the age of 9, increased by 1.4 mm every year.

The relationship between the maxilla and the mandible determines the presence or absence of transverse skeletal discrepancy (7). Cortella et al. reported that the maxilla grows less than the mandible, and this provides normal occlusion (no cross-bite) (25). They found a strong correlation between maxillary width and maxillary intermolar width, between maxillary intermolar width and mandibular intermolar width, and between mandibular width and mandibular intermolar width. These findings are in line with those of Snodell et al. (11).

Mandibular intermolar width. Sillman et al. (26) found a 1.2 mm increase from 7 to 13 years in mandibular intermolar width in men and women, while Moyers found an increase of 1.6 mm in females and 2.6 mm in males from 7 to 16 years (27). In our study, we found an increase of 1.81 mm from the prepubertal stage to the pubertal stage and and increase of 3.32 mm from the prepubertal stage to the postpubertal stage. These results do not support the decrease Woods et al. (28) found in women and men and that Snodell et al. (11) found only in women. This difference may be the result of ethnic differences between nations.

Maxillary intermolar width. Woods et al. found an increase of 2.5 mm in females and 2.6 mm in males between the ages of 7 and 15 years (28). Sillman et al. found a 3 mm increase in males and females between the ages of 7 and 13 years(26). Moyers found an increase of 3.5 mm in females and 4.2 mm in males between the ages of 7 and 16 years (27). Snodell et al. similarly found an increase of 2.1 mm in females and 3.6 mm in males between the ages of 7 to 16 years (11). In our study, we found an increase of 1.98 mm from the prebupertal stage to the pubertal stage and 3.77 mm from the prepubertal stage to the postpubertal stage. These results are similar to those of previous studies. We also found that the Turkish population had values similar to those of the Kuwaiti and American populations for maxillary intermolar width.

Cranial width. In the first stage of skeletal maturation in the Korean population, widths of 160.52 mm in men and 155.12 mm in women have been found (19). Even in the postpubertal stage, our study found the widths to be 133.47 mm in women and 142 mm in men. Compared to other studies (6,8,10,11,18,19,24), it was found that the cranial width of Turks was the smallest. The most similar population was the Irish population.

Facial width. Ricketts (2) found that the facial width was 115.7 mm at age 9 and increased by 2.4 mm per year. In our study, it was found that there was an increase of 2.15 mm from the prepubertal to postpubertal stages. While the facial width of the Turkish population is similar to that of the Irish (10) and American (11) populations at ages 6 and 7, the facial widths of the Irish (10), Americans (11), and other nations (6,8,18,19,24) in the 15–18 age group are greater than the Turks'.

Maxillomandibular width differences. In the first stage of skeletal maturation in the Korean population, the maxillomandibular widths were found to be 17.15 mm in women and 19.37 mm in men. In the last stage, it was found to be 23.70 mm in women and 22.16 mm in men (19). In the Kuwaiti population, it was 19.7 mm in the age range of 13-14 (8). In our study, it was 14.35 mm in women and 15.27 mm in men in the prepubertal stage. In the postpubertal phase, it was 16.52 mm in women and 17.92 mm in men. It can be seen that the maxillomandibular width of the Turkish population is quite small.

Betts et al. reported that surgical expansion was required in cases of a maxillomandibular transverse differential index greater than 5 mm in adult patients (≥15.5 years old) (29). These results were obtained with the norm values being valid for Caucasian individuals. Measured values in our study were greater than 5 mm; however, considering the Turkish individuals included in the study were skeletal Class I with ideal occlusion and no cross-bite, Betts et al.'s results cannot be valid for Turkish individuals.

Maxillomandibular width ratio. Cortella et al. emphasized that the factors of enlargement may vary at different ages, and the mandible is more affected by the maxilla since the mandibular width is greater than the maxillary width (25). He reported that the use of the maxillomandibular ratio would therefore be a more accurate diagnostic guideline (25). Cortella found that the maxillo-mandibular ratio was 78.6% at the age of 6 and 74.9% at the age of 18 (25). Athanasiou found this ratio to be 77.8% at age 6 and 74% at age 15 (24). Hwang stated that in the first phase of \ skeletal maturation, this ratio was 78.83% in women and 77.77% in men, while it was 74.06% in women and 77.01% in men in the last stage (19). In our study, it was 80.13% in women and 79.75% in men in the prepubertal stage. In the postpubertal stage, it was 78.07% in women and 77.85% in men. The decrease in values is similar to that found in other studies (6,19,24,25).

A limitation of our study is that the number of individuals in the skeletal maturation stages was not evenly distributed. To overcome the limitations of a cross-sectional study design, skeletal maturation stages were divided into the prepubertal, pubertal, and postpubertal groups according to hand-wrist radiography and the prespurt and postspurt groups according to lateral cephalometric radiography. Furthermore, the small sample size compared to the sample sizes found in similar studies might also have been a limitation; however, statistical analyses verified that the power of our study is 0.99.

In our study, one-time frame evaluations were made on radiographs taken from individuals. Longitudinal studies involving skeletal maturation are required.

The use of two-dimensional posteroanterior radiographs in our study could also have limited the determination of anatomical landmarks because of superimpositions (30). Hence, even the use of 3D cone beam computed tomography seems to be more advantageous; furthermore, ethical limitations exist due to the high radiation exposure from routine use (1).

Conclusions

Skeletal age and sex should be taken into account when determining transverse dentofacial measurements. Sex was found to be an explanatory factor in all transverse measurements. The values were found to be higher in males than in females. Significant increases in the maxillary, mandibular, mandibular intermolar and maxillary intermolar widths from the prepubertal stage to the postpubertal stage were identified. Maxillary intermolar width significantly increased from the prepubertal stage to the pubertal and postpubertal stages.

Ethical Approval: Ethics committee approval was received for this study from Kırıkkale University Clinical Research Ethics Committee in accordance the World Medical Association Declaration of Helsinki, with the approval number: 2018/16-02.

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