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RESEARCH

Examination of mandibular radiomorphometry in pediatric population according to age and gender

Pediatrik populasyonda mandibular radyomorfometrisinin yaş ve cinsiyete göre araştırılması

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Abstract

Purpose: This study aimed to compare and evaluate mandibular measurements obtained from digital panoramic radiographs in a pediatric population according to age and gender.
Materials and Methods: This retrospective cross-sectional study analysed 100 digital panoramic radiographs of individuals aged 6-13 years (59 females, 41 males). A series of measurements was recorded for specific mandibular structures, including the gonial angle, ramus height and width, corpus length, and anterior corpus height.
Results: Statistically significant differences were observed in mandibular ramus height (R2;53.96, L2;53.61) and mandibular corpus length (R4;81.64, L4;81) parameters across age groups in females, with the lowest values noted in the 6-7 age group. In males, significant differences were found in mandibular ramus height (R2: 45.62, L2: 245.19) parameters according to age, with the 6-year age group exhibiting the lowest mean values (48 ± 0). However, no statistically significant difference was observed in the measured parameters between genders across the age groups.
Conclusion: This investigation revealed no statistically significant differences in the measured mandibular parameters between the sexes. Nevertheless, the observed parameters consistently increased with advancing age, aligning with findings reported in similar studies. Further research employing diverse methodologies in subadult populations is warranted to establish robust standards for sex and age estimation.
Keywords:. Panoramic radiograph, gonial angle, ramus height, gender, mandibula

Öz

Amaç: Bu çalışmanın amacı, dijital panoramik radyograflarda gözlenen mandibular noktaların ölçümlerini yaparak cinsiyete göre karşılaştırmak ve değerlendirmektir.
Gereç ve Yöntem: Bu retrospektif kesitsel çalışmada, 6-13 yaş arası bireylerin (59 kız, 46 erkek) 100 dijital panoramik radyografisi değerlendirildi. Gonial açı, ramus yüksekliği ve genişliği, korpus uzunluğu ve anterior korpus yüksekliği gibi mandibular yapıların ölçümleri yapıldı.
Bulgular: Kadınlarda mandibular ramus yüksekliği (R2;53,96, L2;53,61) ve mandibular korpus uzunluğu (R4;81,64, L4;81) parametrelerinde yaşa göre istatistiksel olarak anlamlı farklılıklar gözlenmiştir; bu değerler 6-7 yaş grubunda daha düşüktür. Erkeklerde, mandibular ramus yüksekliği (R2;45,62, L245,19) parametrelerinde yaşa göre anlamlı farklılıklar bulundu; 6 yaş grubu en düşük ortalama değerlere (48 ±0) sahipti. Yaş gruplarına göre cinsiyetler arasındaki değerlerde ise istatistiksel olarak anlamlı bir fark gözlenmedi.
Sonuç: Bu araştırma, ölçülen mandibular parametrelerde cinsiyetler arasında istatistiksel olarak anlamlı bir fark olmadığını ortaya koymuştur. Bununla birlikte, gözlemlenen parametreler yaşın ilerlemesiyle tutarlı bir şekilde artmıştır ve bu durum benzer çalışmalarda bildirilen bulgularla uyumludur. Cinsiyet ve yaş tahmini için sağlam standartlar oluşturmak amacıyla, ergenlik çağındaki popülasyonlarda çeşitli yöntemler kullanılarak daha fazla araştırma yapılması gerekmektedir.
Anahtar kelimeler: Panoramik radyografi, gonial açı, ramus yüksekliği, cinsiyet, mandibula

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INTRODUCTION

Mandibular structures are essential for fundamental stomatognathic functions, including mastication, articulation, and facial aesthetics. Consequently, their characteristics have consistently been a central focus across various clinical disciplines, such as anatomy, anthropology, plastic and reconstructive surgery, maxillofacial surgery, otolaryngology, and dentistry. Notably, in recent years, the clinical significance of the mandible has increased due to the growing demand for functional and aesthetic outcomes from evolving treatment modalities[1].

In forensic contexts, particularly when an intact skull is unavailable, the mandible is of immense value for sex determination. As the most dimorphic, largest, and strongest bone of the skull, it is also the hardest facial bone, which retains its morphology more effectively than other skeletal elements commonly utilised in forensic and physical anthropology. Mandibular dimorphism is evident in both its shape and size, with male mandibles typically exhibiting larger dimensions and greater robustness compared to female mandibles[2].

The skull and hip bones, which are significantly influenced by sex hormones during pubertal development and bone formation, are considered the most informative skeletal elements for sex identification[3]. However, the use of hip joint radiography should be minimised to reduce potential tissue damage, thus advocating for the use or combination of alternative methods for sex determination. The developmental and functional characteristics of the mandible make it a suitable indicator for an individual's age and sex[4].

Despite consistent observations of sex differences in craniofacial dimensions at birth, reports on mandibular shape and dimensional dimorphism in adulthood and during puberty remain varied (4, 5). Conversely, findings concerning pre-pubertal sex dimorphism are inconsistent[6]. The nature of mandibular dimorphism evolves with development. While size dimorphism persists into adulthood, shape dimorphism, particularly in the ramus and mental region observed at birth, becomes less pronounced between 4 and 14 years of age, primarily due to more rapid growth in females[7].

Radiographic investigations have demonstrated that the adult mandible can be effectively utilised for both sex and population affinity identification, frequently outperforming other standard analytical techniques. Consequently, parameters and methodologies for growing mandibles require validation and standardisation across diverse population groups, taking into account variations in ethnic models.

Given that the development and growth patterns of mandibular points differ between sexes, it is essential to meticulously examine the mandibular ramus and gonial angle in sex dimorphism studies. A recent geometric morphometric (GMM) study, which investigated dimorphism across three distinct populations, concluded that the subadult mandible does not exhibit significant dimorphism[4,8]. Traditionally, morphological methods have relied heavily on the anthropologist's subjective interpretation of sex dimorphism in the mandible, resulting in considerable inter-observer variability [9].

This study aimed to conduct various measurements of specific mandibular landmarks observed on digital orthopantomographs and subsequently compare and evaluate these measurements by gender. This study was planned using panoramic radiography to examine dimorphic changes in the mandible in a population aged 6-13 years in the Afyonkarahisar-Turkey area. The null hypothesis of our study is that there will be changes in the dimensions of the mandible with age.

MATERIALS AND METHODS

Procedure

This study received ethical approval from the Afyonkarahisar Health Sciences University Clinical Research Ethics Committee (Decision No. 2024/43, dated 19 April 2024). This retrospective cross-sectional investigation was conducted at the Department of Pedodontics, Faculty of Dentistry, Afyonkarahisar Health Sciences University. Additionally, the data were obtained from official hospital records, and all file security procedures were carried out with the protocols established by the relevant institution.

All existing Panoramic radiographs (OPG) were obtained from faculty archives, which included basic demographic data (age and gender) and personal data that was concealed, with permission obtained from the ethics committee. Of the 127 panoramic images obtained, 100 were evaluated according to predetermined criteria and included in the study. These images belong to individuals who visited the pediatric dentistry clinic at the Faculty of Dentistry, Afyonkarahisar Health Sciences University between October and December 2023 and were evaluated by pediatric dentists Mehmet Ünal and Rumeysa Çakırcalı. Each measurement was taken twice by the researchers, and the average of the two measurements was used as the final result.

Sample

The inclusion criteria for the study were as follows: individuals aged between 6 and 13 years in mixed dentition with complete demographic information (age and sex) available, along with their panoramic radiographs. Panoramic radiographs provide a comprehensive view of both sides of the mandible, offering optimal intensity and contrast. Images free from projection errors that could compromise radiographic analysis.

Conversely, exclusion criteria for panoramic radiographs included: presence of maxilla or mandible pathology, evidence of mandibular fracture, developmental anomalies of the mandible, craniofacial syndromes, plating for fractures, odontogenic cysts or tumours of the mandible, complete dentures, or edentulous arches. All radiographs were acquired at the Afyonkarahisar Health Sciences University Faculty of Dentistry using a standardised Planmeca Promax 2D (Finland) machine. Subsequently, all panoramic radiographs were processed and printed using Planmeca Romexis software.

Measures

The following measurements were obtained from the panoramic radiographs [8] (Figure 1):

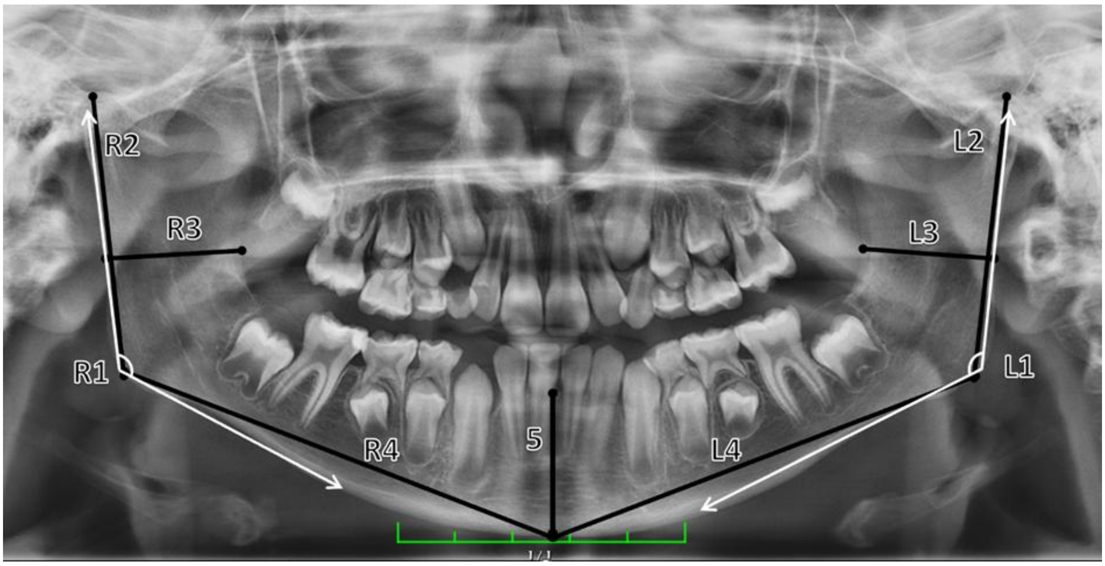

Figure 1: R1-L1: Gonial angles: These are angles measured at the intersection of the borders of the mandibular corpus and the posterior border of the mandibular ramus. R2-L2: Mandibular ramus height: The distance from the Condylion point to the Gonion point. R3-L3: Mandibular ramus widths: The smallest anteroposterior diameter of the mandibular ramus. R4-L4: Mandibular corpus length: The distance from the gonion point to the menton point. 5: The anterior mandibular corpus height is defined as the distance from the alveolar crest to the mandibular lower margin on the mid-sagittal line. (R: right, L: left).

R1-L1: Gonial Angle: Measured at the intersection of the inferior border of the mandibular corpus and the posterior border of the mandibular ramus.

R2-L2: Mandibular Ramus Height: The linear distance from the Condylion point to the Gonion point.

R3-L3: Mandibular Ramus Width: Defined as the smallest anteroposterior diameter of the mandibular ramus.

R4-L4: Mandibular Corpus Length: The linear distance from the Gonion point to the Menton point.

5: Anterior Mandibular Corpus Height: Defined as the linear distance from the alveolar crest to the inferior border of the mandible along the mid-sagittal line.

Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics Standard Concurrent User V 26 (IBM Corp., Armonk, NY, USA). Intra-class correlation coefficients (ICCs) were calculated to assess intra-observer consistency between repeated measurements, along with 95% confidence intervals. Descriptive statistics were presented as the number of units (n), percentage (%), minimum, maximum, and mean ± standard deviation. The normality of numerical variables was assessed using the Shapiro-Wilk normality test. When comparing two groups, the independent samples t-test was used when the data were normally distributed, and the Mann-Whitney U test was used when the data were not normally distributed. For variables with more than two categories, one-way analysis of variance (ANOVA) was used when the data were normally distributed, and the Kruskal-Wallis H test was used when the data were not normally distributed. The Dunn-Bonferroni test was used for multiple comparisons when the ANOVA result was significant. The Spearman correlation test was used to evaluate the relationship between variables. $p<0.05$ was considered statistically significant.

RESULTS

The intra-class correlation coefficients (ICCs) were greater than 0.90, indicating excellent intra-observer consistency. Table 1 presents the descriptive characteristics of the panoramic radiographs included in the study. In females, statistically significant differences were observed in the R2, L2, R4, and L4 parameters across various age groups ($p < 0.05$). Specifically, a clear distinction was noted between the R2 and L2 parameters for the 6- and 7-year-old groups and older age categories, with the younger groups demonstrating lower values. Conversely, higher mean values were observed in the older age groups. A similar trend was evident for the R4 and L4 parameters, where 6-year-olds exhibited lower mean values, while higher values were observed in the 10-, 11-, and 13-year-old age groups (Table 2).

For males, a statistically significant difference in R2 and L2 parameters was identified across age groups ($p < 0.05$). A significant difference was found between the 6-year-old age group and all other age categories, with the 6-year-olds exhibiting a lower mean and the different age groups demonstrating higher mean values (Table 3).

Table 1: Descriptive statistics

Variable	Statistics
Gender	
Female	59 (%56.19)
Male	46 (%43.81)
Age	
6	10 (%9.52)
7	14 (%13.33)
8	11 (%10.48)
9	24 (%22.86)
10	15 (%14.29)
11	11 (%10.48)
12	7 (%6.67)
13	13 (%12.38)
R1	129.61±4.68
L1	129.37±4.69
R2	52,88±7.66
L2	52,41±7.66
R3	28.81±3.47
L3	28.75±3.55
R4	80.85±10.57
L4	80.52±10.95
5	28.22±4.78
magnification	47.73±0.94

R1-L1: Gonial angles, R2-L2: Mandibular ramus height, R3-L3: Mandibular ramus widths, R4-L4: Mandibular corpus length, 5: The anterior mandibular corpus height

No statistically significant difference was observed between genders for any of the measured parameters across the age groups (Table 4). The relationships between numerical variables were analysed by correlation analysis (Table 5). R1-L1, R2-L2, R2-R4, R2-L4, R2-5, L2-R4, L2-L4, L2-5, R3-L3, R4-L4, R4-5, L4-5 showed a significant strong positive correlation. Age-related changes in the parameters are presented in Figures 2 and 3.

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Table 2. Comparison of parameters by age in girls

Variable	6	7	8	9	10	11	12	13	Statistics	p
R1	130.19±5.33	129.77±3.04	128.57±3.84	131±4.93	128.69±4.69	129.95±5.36	125,06±5,75	128,09±6,14	6,508	0,482€
L1	129.41±5.78	130.57±2.96	128.7±4.66	129.76±4.03	128.41±4.64	129.35±4.92	124,91±5,74	127,2±7,6	5,276	0,626€
R2	44.98±3.4a	47.41±6.39a	52.28±4.42b	51.94±8.63b	56.59±8.19b	57.42±9.38b	55,22±6,24b	61,36±7,41b	21,692	0,003€
L2	45.25±2.85a	47.05±6a	51.82±5.17b	51.41±9.1b	56.1±7.79b	56.77±9.05b	55.31±6.98b	61.03±7.69b	21.480	0.003€
R3	26.55±2.72	28.67±3.1	30.68±3.54	26.78±4.3	30.97±2.52	28.17±1.9	29.01±4.38	30.31±3.2	12.468	0.086€
L3	25.77±2.61	28.19±2.31	29.38±2.49	27.39±4.61	31.05±2.92	27.96±1.84	29.55±5.49	30.31±3.51	11.961	0.102€
R4	70.51±5.29a	76.68±10.12ab	80.04±10.32ab	77.28±9.82ab	87.3±10.36b	83.89±10.04b	80.15±11.33ab	90.02±9.31b	17.554	0.014€
L4	68.27±6.88a	75.34±9.4ab	78.6±10.93ab	78.88±10.05ab	86.8±10.49b	83.2±10.53b	79.53±12.88ab	89.43±11.01b	17.852	0.013€
5	23.56±2.4	25.23±3.42	27.69±2.85	27.66±5.79	30.89±4.79	30.67±5.2	28.52±4.3	32.28±5.42	13.853	0.054€
magnification	47.83±0.41	47.71±0.49	47.5±0.55	48.63±3.02	47.45±0.52	47.57±0.53	47.6±0.55	47.44±0.53	3.807	0.802€

Numerical variables are given as mean±standard deviation. £: One-way ANOVA, € Kruskal-Wallis test. R1-L1: Gonial angles, R2-L2: Mandibular ramus height, R3-L3: Mandibular ramus widths, R4-L4: Mandibular corpus length, 5: The anterior mandibular corpus height

Table 3. Comparison of parameters by age in men

Variable	6	7	8	9	10	11	12	13	Statistics	p
R1	129.52±4.28	129.14±3.45	130.19±4.77	130.54±4.34	130.35±6.93	130.49±3.18	134.71±7.23	130.76±3.99	1.988	0.961€
L1	128.21±4.12	129.61±3.36	129.84±5.17	130.12±3.57	131.67±6.25	131.48±4.34	132.77±2.35	131.63±3.16	0.3271	0.859€
R2	45.62±1.65a	51.25±6.47b	50.66±5b	49.87±5.24b	51.86±4.64b	55.15±4.54b	52.53±0.67b	60.81±9.07b	16.721	0.019€
L2	45.19±1.11a	50.96±6.63b	50.48±5.26b	48.74±4.97b	52.85±5.26b	54.28±4.15b	50.27±1.94b	60.24±8.93b	18.310	0.011€
R3	26.21±3.31	28.9±3.62	27.54±5.66	28.49±3.12	28.19±2.23	28.55±3.28	26.42±3.44	32.71±1.33	8.897	0.260€
L3	26.2±2.65	28.6±3.89	27.67±4.57	28.62±3.47	28.88±2.39	28.69±2.81	25.52±1.73	32.83±3.83	8.524	0.289€
R4	68.43±6.55	78.34±10.02	79.22±12.12	78.96±8.04	81.51±9.91	79.96±4.37	82.13±4.91	95.36±11.19	12.709	0.080€
L4	69.29±4.91	77.02±9.72	79.58±10.8	78.68±7.93	82.04±10.75	80.85±5.03	82.73±4.7	96.41±12.85	13.928	0.052€
5	22.59±2.84	26.63±3.81	28.15±4.38	26.59±2.07	27.34±7.63	28.5±4.78	28.03±2.03	33.11±3.83	13.199	0.067€
magnification	48±0	47.57±0.53	47.8±0.45	47.88±0.34	47.75±0.5	47.75±0.5	48±0	47.25±0.5	9.975	0.190€

Numerical variables are given as mean±standard deviation. £: One-way ANOVA, € Kruskal-Wallis test. R1-L1: Gonial angles, R2-L2: Mandibular ramus height, R3-L3: Mandibular ramus widths, R4-L4: Mandibular corpus length, 5: The anterior mandibular corpus height

Table 4. Comparison of parameters by gender

	Female	Male	Statistics	p
R1	129.02±4.92	130.38±4.29	-1.482	0.141‡
L1	128.61±5.13	130.34±3.89	-1.904	0.060‡
R2	53.96±8.52	51.49±6.2	-1.631	0.103†
L2	53.61±8.47	50.86±6.22	-1.805	0.071†
R3	29.05±3.44	28.51±3.52	0.796	0.428‡
L3	28.9±3.55	28.56±3.59	-0.762	0.446†
R4	81.64±10.95	79.85±10.09	-0.775	0.438†
L4	81±11.59	79.91±10.16	-0.575	0.565†
5	28.92±5.08	27.32±4.27	-1.328	0.184†
Magnification	47.71±1.2	47.76±0.43	-1.814	0.070†

Numerical variables are given as mean±standard deviation. ‡: Independent samples t-test, †Mann-Whitney U test. R1-L1: Gonial angles, R2-L2: Mandibular ramus height, R3-L3: Mandibular ramus widths, R4-L4: Mandibular corpus length, 5: The anterior mandibular corpus height

Table 5. Correlations among study variables.

		R1	L1	R2	L2	R3	L3	R4	L4	5
L1	*rho*	**.885****								
	p	**0.001**								
R2	*rho*	**-.212***	-0.132							
	p	**0.030**	0.178							
L2	*rho*	**-.239***	-0.157	**.975****						
	p	**0.014**	0.109	**0.001**						
R3	*rho*	**-.295****	-0.181	**.649****	**.643****					
	p	**0.002**	0.064	**0.001**	**0.001**					
L3	*rho*	**-.270****	-0.184	**.675****	**.696****	**.899****				
	p	**0.005**	0.061	**0.001**	**0.001**	**0.001**				
R4	*rho*	-0.167	-0.077	**.845****	**.845****	**.745****	**.754****			
	p	0.088	0.434	**0.001**	**0.001**	**0.001**	**0.001**			
L4	*rho*	-0.122	-0.037	**.841****	**.845****	**.708****	**.759****	**.970****		
	p	0.215	0.709	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**		
5	*rho*	-0.110	-0.036	**.823****	**.808****	**.662****	**.707****	**.824****	**.823****	
	p	0.282	0.728	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	**0.001**	

rho = Spearman's rank correlation coefficient; Bold values indicate statistically significant correlations at $p < 0.05$ ($p < 0.05$*, $p < 0.01$**). R1-L1: Gonial angles, R2-L2: Mandibular ramus height, R3-L3: Mandibular ramus widths, R4-L4: Mandibular corpus length, 5: The anterior mandibular corpus height

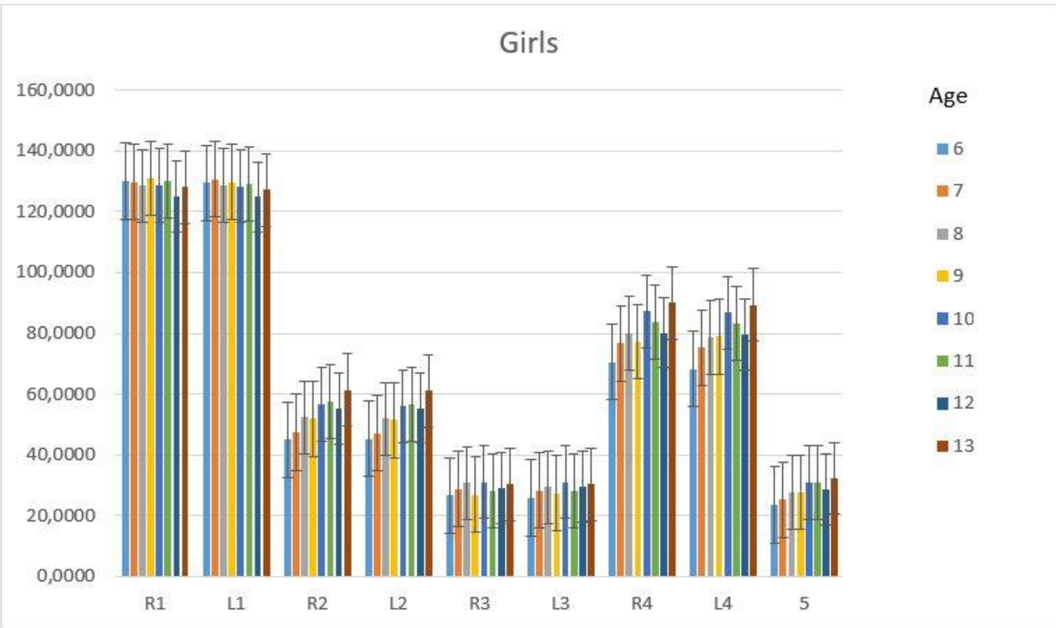

Figure 2. Age-related changes in parameters among girls.

R1-L1: Gonial angles, R2-L2: Mandibular ramus height, R3-L3: Mandibular ramus widths, R4-L4: Mandibular corpus length, 5: The anterior mandibular corpus height

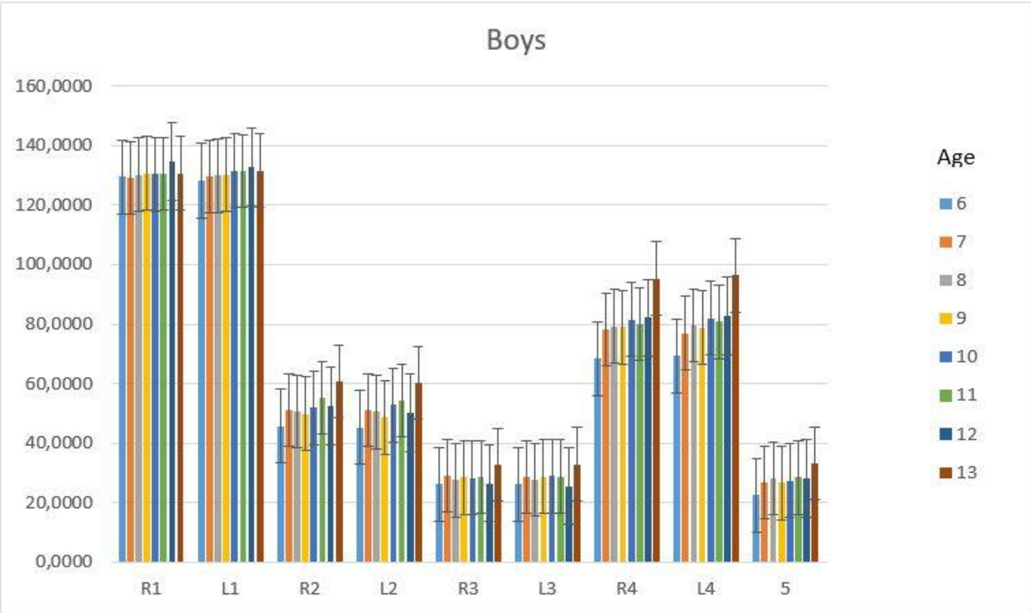

Figure 3. Age-related changes in parameters among boys.

R1-L1: Gonial angles, R2-L2: Mandibular ramus height, R3-L3: Mandibular ramus widths, R4-L4: Mandibular corpus length, 5: The anterior mandibular corpus height

DISCUSSION

This study's objective was to develop for future applications in determining age and gender categorisation based on the morphological structure of bone, particularly using images obtained from panoramic radiographs. The mandibula, the strongest of all facial bones, plays a vital role in forensic odontology for determining age and gender. Its dense cortical bone structure ensures durability, making it ideal for analysis and study. The mandibula exhibits significant sexual dimorphism, primarily shaped by genetic predispositions during the developmental period, which differentiate male and female growth patterns[10].

Ulusoy et al. demonstrated a lack of gender dimorphism in the growing mandible, which aligns with the results of the present study in a Turkish population. However, they suggested that more studies should be carried out in adult and elderly subpopulations to establish standards for gender and age estimation, as there are currently insufficient studies in the Turkish population[11]. This study examines differences in age and gender based on four mandibular measurements: condylar-ramus height (from the condyle tip to its intersection with the gonion), mandibular ramus width, the angle between the inferior mandibular corpus and posterior mandibular ramus, and mandibular corpus length.

The facial skeleton develops throughout a person's life, and it has been reported that different parts of the face grow at different rates. Clinical evidence also shows that some people's mandible can change shape as they age. In surgery, any change in the size and shape of the mandibula is extremely important[12]. Our study's results showed a statistically significant difference was found in mandibular ramus height parameters (R2 and L2) according to age in boys and girls. Additionally, significant statistical differences were observed in mandibular corpus length (R4 and L4) parameters in the girls' group according to age.

The gonial angle and the antegonial region of the mandibula are among the most critical indicators of age. The gonial angle decreases with age during adulthood. These changes have been reported to persist into old age in both males and females. It has been reported that ramus height and mandibular body length show a strong correlation with chronological age[12-14] Datta et al. demonstrated that mandibular parameters, including gonial angle, bigonial width, ramus height, bicondylar width, mandibular length, mandibular index, body thickness, coronoid height, bimental width, symphysial height, and body height, are valuable tools for gender determination[15]. In the pediatric age group studied, while the gonial angle appeared to increase with age, no statistically significant difference was found. The shift in ramus width and height with age was found to be substantial.

Mandibula and maxilla differ morphologically between males and females. Measured on the mandible and maxilla in the Surabaya population, statistically significant differences between the genders were found in all variables except mandibular ramus dimensions[16]. In this study, radiomorphological analysis was employed to quantify discrepancies based on age and gender. Our data indicated that while males had larger mandibular dimensions than females, no statistically significant difference was found.

Taleb et al. reported that, among the Egyptian population, condylar and coronoid height were the best predictors for sex determination, with an overall accuracy of 79.6% [17]. Similarly, in a more recent study, Sandeepa et al. reported that the highest sexual dimorphism was associated with maximum ramus width and coronoid height, followed by condylar height. The least dimorphism was associated with the minimum ramus width in their study of the Saudi population [18]. These studies suggest that gender accuracy can be determined not only in adults but also in developing individuals [4]. However, our study observed changes related to age but not to gender. However, to clarify this, we believe that further studies with a larger sample size, as noted in the limitations of our study, will provide greater clarity.

Motawei et al. found that gender dimorphism in mandibular ramus length becomes evident only after the age of 17, with no significant differences observed between males and females in the 7- to 17-year-old age group. It concluded that while mandibular ramus length is applicable for age estimation, it is less effective for determining gender [3]. Leversha et al. found that males had a greater ramus height than females; however, females had a greater gonial angle on average. There was a steady decrease in ramus height later in life, with the gonial angle generally increasing with age[19]. Kelly et al. The results of their studies show that structures in the horizontal plane, such as condylar width and mandibular body length, generally mature earlier than structures in the vertical plane, such as ramus depth. Differences in growth rate between males and females obscure prepubertal gender dimorphism, particularly since the direction of dimensional differences varies across different variables[7]. In our study, no statistically significant differences were identified between gender parameters across age groups. A possible reason for the absence of this difference may be that gender-based differences are minimal during the prepubertal period.

This research, which focused on various mandibular measurements from digital orthopantomograms in a Turkish population, revealed no statistically significant differences between genders. However, consistent with findings from other studies, we observed that these parameters generally increased with age. Additionally, the study's limited geographic area is also a major limitation

We believe that the lack of statistical differences in this study is due to fewer gender differences during the prepubertal period. The limited sample size is another limitation of this study, which may also contribute to this result.

We recommend further investigation using alternative methodologies in subadult populations to establish robust standards for both sex and age estimation. The data presented here can serve as a valuable normative reference for several disciplines, including dentistry, maxillofacial surgery, and forensics.

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