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Tweed Cephalometric Norms by Malocclusion Type and Gender in Turkish Adolescents: A Cross-sectional Analysis

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ABSTRACT

Objective: This study aims to evaluate the relationship and differences in Tweed cephalometric analysis measurements according to malocclusion type and gender in individuals with different dental and skeletal malocclusions. A secondary aim is to contribute to the establishment of reference values for the Turkish subjects.
Materials and Methods: This retrospective study included cephalometric radiographs of 200 individuals, with an equal number of males and females in each dental malocclusion group (50 individuals per group). Dental malocclusion was classified according to Angle's classification. In contrast, skeletal malocclusion was classified based on the ANB angle. The FMA, FMIA, and IMPA angles, which are part of the cephalometric analysis proposed by Tweed, were measured. Statistical analyses of dental and skeletal malocclusion, gender, and their interactions were conducted using MANOVA analysis.
Results: The FMA angle did not show a difference between the groups according to the dental or skeletal malocclusion type. The FMIA angle was similar in individuals with dental and skeletal Class I (C-I) and Class II (CI-I) malocclusions but markedly lower in Class III (C-III) individuals ($p<0.05$). The IMPA angle was lowest in C-III individuals and highest in C-II individuals for both dental and skeletal malocclusions ($p<0.05$). The Tweed Cephalometric Analysis measurements showed no difference between the genders.
Conclusions: The mean FMA angle obtained in this study was similar to the values proposed by Tweed, whereas the mean FMIA and IMPA angles differed. While the FMA angle did not vary according to dental and skeletal malocclusion, the FMIA and IMPA angles showed significant differences.

***Keywords*:** Malocclusion, radiography, cephalometry.

Türk Adölesanlarda Maloklüzyon Tipi ve Cinsiyete Göre Tweed Sefalometrik Normları: Kesitsel Bir Analiz

Araştırma Makalesi

Süreç

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ÖZ

Amaç: Bu çalışmada farklı dental ve iskeletsel maloklüzyona sahip bireylerde Tweed sefalometrik analiz ölçümlerinin maloklüzyon ve cinsiyete göre ilişkisi ve farklılıklarının değerlendirilmesi amaçlanmıştır. İkincil amaç olarak ise Türk popülasyonu için referans değerlerin gösterilmesi açısından katkı sağlanması hedeflenmektedir.
Gereç ve Yöntemler: Retrospektif olarak planlanan bu çalışmaya her bir dental maloklüzyon grubunda kadın ve erkek aynı sayıda olmak üzere 50 birey toplam 200 bireye ait sefalometrik radyografiler dahil edilmiştir. Dental maloklüzyon incelemesi Angle sınıflamasına, iskeletsel maloklüzyon sınıflaması ise ANB açısına göre gerçekleştirilmiştir. Tweed tarafından önerilen sefalometrik analize ait FMA, FMIA ve IMPA açılarının ölçümleri gerçekleştirilmiştir. Dental ve iskeletsel maloklüzyon ile cinsiyetlere ve bunların etkileşimine ait istatistiksel değerlendirmeler MANOVA analizi kullanılarak gerçekleştirilmiştir.
Bulgular: FMA açısı hem dental hem de iskeletsel maloklüzyona göre farklılık göstermemektedir. FMIA açısı dental ve iskeletsel sınıf I ve II bireylerde benzer ve sınıf III bireylerden daha düşük olarak bulunmuştur ($p<0.05$). Dental ve iskeletsel maloklüzyonlarda IMPA açısı en düşük sınıf III bireylerde en yüksek ise sınıf II bireylerde bulunmuştur ($p<0.05$). Tweed sefalometrik analiz ölçümleri cinsiyetler arasında farklı değildir.
Sonuçlar: Çalışmadan elde edilen FMA açısı ortalama değerleri Tweed tarafından önerilen ile benzer iken FMIA ve IMPA açılarının ortalama değerleri farklıdır. Dental ve iskeletsel maloklüzyona göre FMA açısı farklılık göstermez iken FMIA ve IMPA açıları farklılık göstermektedir.

Anahtar kelimeler: Maloklüzyon, radyografi, sefalometri.

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Introduction

Radiographic cephalometry, which is used for various purposes such as evaluating dentofacial proportions, explaining the anatomical basis of orthodontic malocclusion, diagnosing and planning the treatment of orthodontic cases, and assessing treatment outcomes, was introduced as both a research and clinical tool in 1934 by Hofrath in Germany and Broadbent in the United States.[1] For this reason, lateral cephalometric radiographs

are commonly used as an auxiliary diagnostic tool in orthodontic examinations and treatments on a case-by-case basis.[2,3] Since the advent of cephalometric radiographs, numerous researchers have proposed and utilized various analytical methods, and these analyses have been used to examine specific norms for different populations.[3-6] Among these, the most frequently used methods, both in the past and today, are those developed by Downs, Steiner, and Tweed.[3,79]Steiner defined one of the most widely studied cephalometric parameters, the ANB angle (A point, nation, and B point), to evaluate the positional relationship between the maxilla and mandible.[3,4,7] Unlike Angle's philosophy of non-extraction orthodontic treatment, Tweed devoted his career to analyzing the boundaries of the dentition in the anterior region. As a result of these investigations, he advocated for extraction-based orthodontic treatment.[3,4,9] To support his approach, he introduced the "Tweed Diagnostic Triangle," which was appropriate at its introduction and remains relevant today.[3,9]

The Tweed diagnostic triangle consists of three planes (the Frankfort horizontal plane, the mandibular plane, and the long axis of the lower incisor) and three angular measurements formed by these planes: the Frankfort-mandibular incisor angle (FMIA), the Frankfort-mandibular plane angle (FMA), and the incisor-mandibular plane angle (IMPA).[3,4] Later, Tweed incorporated the ANB angle into his analysis to evaluate jaw growth and development direction.[4] Additionally, the Tweed analysis is simple and can be used with other cephalometric analyses.[8] Since the cephalometric values obtained from analyses vary among ethnic groups, establishing normative values for different populations worldwide is an ongoing process.[5,6,10-12] One of the fundamental principles of cephalometric analysis is to compare participants with a standard reference group and to identify differences between racial and ethnic groups regarding authentic dentofacial relationships.[3,5] Several studies have examined the normative values of the Tweed analysis across various populations using reference groups.[5,8-13] However, studies investigating the Tweed cephalometric analysis in the Turkish population are limited.

Therefore, the primary aim of this study is to evaluate the relationship and differences in Tweed cephalometric analysis measurements according to malocclusion type and gender in individuals with different dental and skeletal malocclusions. A secondary objective is to contribute to the establishment of normative values for the Turkish subjects.

Materials and Methods

Study Design

At the beginning of this retrospectively designed study, approval was obtained from the Clinical Research Ethics Committee of Erciyes University (Approval date: 31/01/2024; Approval number: 2024/64). The study was carried out according to the Declaration of Helsinki, and informed consent forms were obtained from all individuals at the beginning of the study. Cephalometric radiographs of individuals who applied to the Department of Orthodontics at the Faculty of Dentistry, Erciyes University, for orthodontic treatment were included in the study. The study design and flow chart are shown in Figure 1.

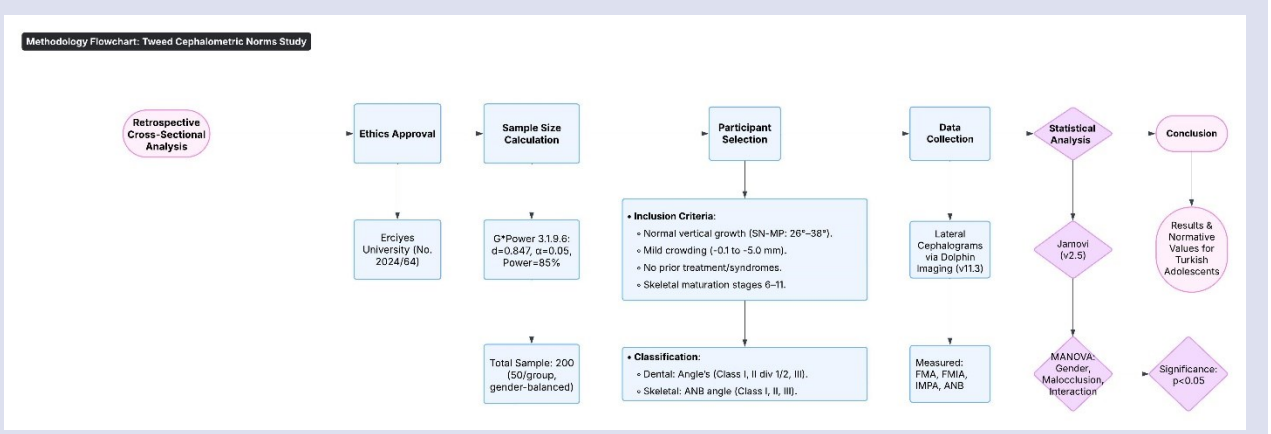

Figure 1. Methodology flowchart: Tweed cephalometric norms study.

Sample Size Calculation

Based on the results reported by Kumari et al.,[5] the required sample size was determined using G*Power software (Ver. 3.1.9.6, Universität Dusseldorf, Germany)[14] with parameters of d = 0.847, α = 0.05, and 85% power, indicating that at least 21 samples were needed per group. Considering possible data loss, 200 individuals were included, with 25 individuals per group and an equal number of males and females in each group to ensure a balanced gender-based evaluation.

Participant Selection

The inclusion criteria were as follows:

- Having normal vertical facial development (26° < SN-MP angle < 38°)[15],
- Having mild crowding (-0.1 and -5.0 mm)[16],
- No prior orthodontic treatment or orthognathic surgery history,

• Absence of syndromic conditions or craniofacial abnormalities,

• No record of trauma affecting the jaw or facial region,

• Sufficient radiographic and orthodontic diagnostic records,

• Skeletal maturation stages between stages 6 and 11 based on hand-wrist radiographs.[17]

The age and gender distribution (demographic) of the individuals included in the study and their statistical evaluation by groups are given in Table 1.

Table 1. Demographic characteristics

		Male		Female		Total		p values
		N (%)	Age (years)	N (%)	Age (years)	N (%)	Age (years)	
Dental Malocclusion	Class I	25 (25)	14.76 ± 1.01	25 (25)	14.60 ± 1.12	50 (25)	14.68 ± 1.06	0.997*
	Class II Division 1	25 (25)	14.59 ± 1.15	25 (25)	14.42 ± 1.33	50 (25)	14.51 ± 1.23	
	Class II Division 2	25 (25)	14.67 ± 1.40	25 (25)	14.40 ± 0.96	50 (25)	14.53 ± 1.19	
	Class III	25 (25)	14.04 ± 1.16	25 (25)	13.80 ± 1.55	50 (25)	13.92 ± 1.37	
Skeletal Malocclusion	Class I	25 (25)	14.76 ± 1.01	25 (25)	14.60 ± 1.12	50 (25)	14.68 ± 1.06	0.992*
	Class II	50 (50)	14.63 ± 1.26	50 (50)	14.41 ± 1.15	100 (50)	14.52 ± 1.21	
	Class III	25 (25)	14.04 ± 1.16	25 (25)	13.80 ± 1.55	50 (25)	13.92 ± 1.37	
Total		100 (50)	14.52 ± 1.20	100 (50)	14.31 ± 1.28	200 (100)	14.41 ± 1.24	

*N: Number of individuals. %: Percentage. N: Number of individuals. Data are given as mean ± standard deviation. * Results of Pearson Chi-Squared test.*

Data Collection

The Tweed cephalometric analysis used in this study includes measurements based on the Frankfort horizontal plane, the mandibular plane, and the long axis of the lower central incisor (Figure 2). Like Downs, Tweed defines the mandibular plane by drawing a tangent from the Menton (M) point to the posterior inferior border of the mandibular corpus.[4,9]

The measurements used in this analysis include (Figure 2):

• The FMA angle, which is the angle between the Frankfort horizontal plane (FH), passing through the porion and orbitale points, and the mandibular plane,

• The FMIA angle, which is the angle between the FH plane and the long axis of the lower central incisor,

• The IMPA angle is the angle between the mandibular plane and the long axis of the lower central incisor.

Additionally, the ANB angle, formed between the Nasion (N), A point, and B point, was measured to classify skeletal malocclusion [Skeletal Class I (C-I), Class II (C-II), Class III (C-III)].[4] Dental malocclusion classification was conducted according to the method proposed by Angle [Dental Class I (C-I), Class II (C-II) division 1 and 2, Class III (C-III)].[4] These methods were chosen due to their widespread use in orthodontic practice and research, facilitating comparison with previous studies.[5,8,11] Cephalometric measurements were performed using Dolphin Imaging Software (Version 11.3, USA). The SN/MP angle was used to evaluate vertical facial growth.

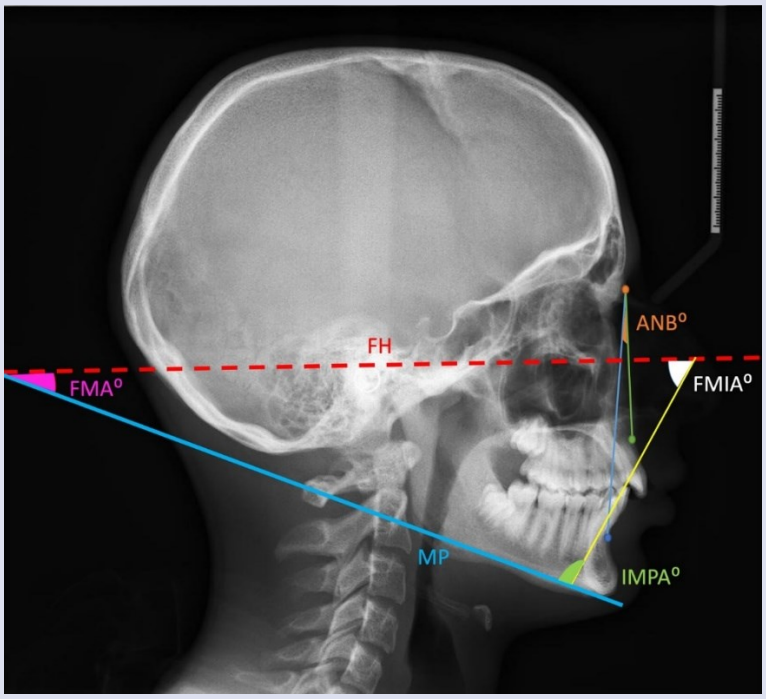

Figure 2. Visual presentation of measurements. FH: Frankfort Horizontal plane. MP: Mandibular plane. ANB: Angle formed between A point, Nasion, and B point. FMA: Frankfort-mandibular plane angle. FMIA: Frankfort-mandibular incisor angle. IMPA: Angle between the mandibular plane and the long axis of the lower central incisor.

Statistical Analysis

The obtained data were recorded using Microsoft Excel software (Microsoft Office 365, Microsoft, Redmond, Washington, USA), and statistical analysis of the data was performed using Jamovi software (Version 2.5, Jamovi Project, Sydney, Australia) based on the R programming language.[18] The dental and skeletal malocclusion assessment, gender, and their interactions were conducted using Multivariate ANOVA (MANOVA). The F-values, statistical values, partial eta squared (η^2) values and mean ± standard deviation (SD) values obtained from the MANOVA analysis are reported. The $p < 0.05$ was used as the statistical significance value.

Results

There was no difference in the distribution of genders among the groups ($p > 0.05$). The mean ages of the individuals were similar between the groups. The study examined data from 200 individuals (14.41 ± 1.24 years), 100 male (14.52 ± 1.20 years), and 100 female (14.31 ± 1.28 years) individuals (Table 1). Individuals' mean dental crowding amounts were -1.84 ± 2.24 mm for the maxilla and -1.68 ± 1.89 mm for the mandible.

Table 2. MANOVA results table regarding the effect of gender and dental malocclusion factors on FMA, FMI and IMPA parameters

Factor	Parameter	F	P values	Partial Eta Squared
Gender	FMA	0.99	0.322	0.01
	FMIA	1.24	0.267	0.01
	IMPA	1.20	0.275	0.01
Dental Malocclusion	FMA	1.09	0.356	0.02
	FMIA	12.57	***<0.001***	0.16
	IMPA	19.12	***<0.001***	0.23
Gender*Dental Malocclusion	FMA	0.16	0.922	0.00
	FMIA	0.11	0.954	0.00
	IMPA	0.59	0.620	0.01

Table 3. Descriptive statistics of FMA, FMIA and IMPA parameters according to dental malocclusion and gender factors

Dental Malocclusion	Gender	N	FMA	FMIA	IMPA
Class I	Male	25	25.62 ± 6.88	61.20 ± 13.34	89.73 ± 7.47
	Female	25	26.01 ± 6.16	60.49 ± 7.34	93.51 ± 6.20
	Total	50	25.82 ± 6.47	60.84 ± 10.66^{A}	91.62 ± 7.06^{A}
Class II Division 1	Male	25	25.30 ± 5.33	58.69 ± 10.90	96.01 ± 9.19
	Female	25	27.22 ± 6.37	56.12 ± 6.08	96.67 ± 6.64
	Total	50	26.24 ± 5.88	57.43 ± 8.88^{A}	96.33 ± 9.16^{B}
Class II Division 2	Male	25	23.88 ± 7.21	59.76 ± 8.26	96.37 ± 8.11
	Female	25	24.56 ± 6.05	58.86 ± 8.21	96.60 ± 7.04
	Total	50	24.23 ± 6.58	59.30 ± 8.16^{A}	96.48 ± 7.50^{B}
Class III	Male	25	25.24 ± 6.21	68.70 ± 9.49	86.05 ± 8.79
	Female	25	26.64 ± 4.92	67.13 ± 7.36	86.25 ± 6.09
	Total	50	25.96 ± 5.58	67.90 ± 8.42^{B}	86.15 ± 7.46^{C}
Total	Male	100	25.03 ± 6.36	61.98 ± 11.24	92.14 ± 9.92
	Female	100	26.12 ± 5.90	60.60 ± 8.25	93.29 ± 7.69
	Total	200	25.58 ± 6.14	61.29 ± 9.85	92.72 ± 8.87

N: Number of individuals. Data are given as mean ± standard deviation. Capital letters in columns indicate pairwise comparisons between dental malocclusion groups.

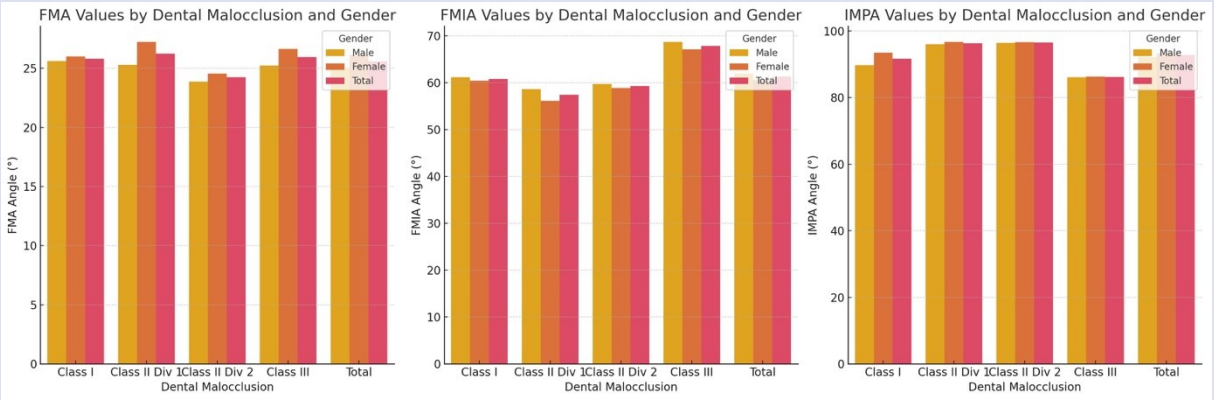

Figure 3. Descriptive statistics of FMA, FMIA, and IMPA parameters by dental malocclusion and gender. The bar graphs represent the mean values for each group.

The results of the MANOVA analysis, which evaluated the effects of gender and dental malocclusion on FMA, FMIA, and IMPA angles, are presented in Table 2. At the same time, the mean ± standard deviation values for the variables are shown in Table 3 and Figure 3. There was no significant relationship between gender or the

gender*dental malocclusion interaction with FMA, FMIA, and IMPA angles. The FMA angle did not show any significant differences among dental malocclusion groups. However, a significant relationship was found between dental malocclusion and FMIA ($p < 0.001$) and IMPA ($p < 0.001$) angles. The FMIA angle was significantly lower in C-III malocclusion compared to other malocclusion types. The IMPA angle was lowest in Class III malocclusion and highest in C-II division 1 and C-II division 2 individuals.

The results of the MANOVA analysis, which evaluated the effects of gender and skeletal malocclusion on FMA, FMIA, IMPA, and ANB angles, are presented in Table 4. At the same time, the mean ± standard deviation values for the variables are shown in Table 5 and Figure 4**.** Tweed cephalometric analysis measurements did not differ according to gender* skeletal malocclusion interaction. ANB angle was the only parameter that showed an essential difference between genders, with females having significantly higher ANB values than males ($p = 0.007$). The FMA angle did not show significant differences among skeletal malocclusion groups. Regarding skeletal malocclusion, the FMIA angle was similar in skeletal C-I and C-II malocclusions but was significantly lower in C-III malocclusion ($p < 0.001$). The IMPA ($p < 0.001$) and ANB ($p < 0.001$) angles had their highest values in skeletal C-II malocclusion and their lowest values in skeletal C-III malocclusion.

Table 4. MANOVA results table regarding the effect of gender and skeletal malocclusion factors on FMA, FMI, IMPA and ANB parameters

Factor	Parameter	F	P values	Partial Eta Squared
Gender	FMA	1.22	0.270	0.01
	FMIA	0.96	0.328	0.00
	IMPA	1.59	0.209	0.01
	ANB	7.34	***0.007***	0.04
Skeletal Malocclusion	FMA	0.24	0.785	0.00
	FMIA	18.34	***<0.001***	0.16
	IMPA	28.95	***<0.001***	0.23
	ANB	309.73	***<0.001***	0.76
Gender * Skeletal Malocclusion	FMA	0.11	0.897	0.00
	FMIA	0.05	0.947	0.00
	IMPA	0.89	0.413	0.001
	ANB	2.56	0.080	0.003

Table 5. Descriptive statistics of FMA, FMIA,IMPA and ANB parameters according to skeletal malocclusion and gender factors

Skeletal Malocclusion	Gender	N	FMA	FMIA	IMPA	ANB
Class I	Male	25	25.62 ± 6.88	61.20 ± 13.34	89.73 ± 7.47	1.51 ± 1.29
	Female	25	26.01 ± 6.16	60.49 ± 7.34	93.51 ± 6.20	1.92 ± 1.54
	Total	50	25.82 ± 6.47	60.84 ± 10.66 ^{A}	91.62 ± 7.06 ^{A}	1.71 ± 1.42 ^{A}
Class II	Male	50	24.64 ± 6.26	59.19 ± 9.66	96.18 ± 9.76	5.93 ± 1.93
	Female	50	25.92 ± 6.29	57.46 ± 7.26	96.64 ± 6.77	6.17 ± 1.92
	Total	100	25.28 ± 6.28	58.33 ± 8.55 ^{A}	96.41 ± 8.36 ^{B}	6.05 ± 1.92 ^{B}
Class III	Male	25	25.24 ± 6.21	68.70 ± 9.49	86.05 ± 8.79	-3.15 ± 3.13
	Female	25	26.64 ± 4.92	67.13 ± 7.36	86.25 ± 6.09	-1.40 ± 1.60
	Total	50	25.96 ± 5.58	67.90 ± 8.42 ^{B}	86.15 ± 7.46 ^{C}	-2.26 ± 2.60 ^{C}
Total	Male	100	25.03 ± 6.36	61.98 ± 11.24	92.14 ± 9.92	2.65 ± 4.31 ^{a}
	Female	100	26.12 ± 5.90	60.60 ± 8.25	93.29 ± 7.69	3.24 ± 3.64 ^{b}
	Total	200	25.58 ± 6.14	61.29 ± 9.85	92.72 ± 8.87	2.94 ± 3.99

N: Number of individuals. Data are given as mean ± standard deviation. Capital letters in columns indicate pairwise comparisons between skeletal malocclusion groups.

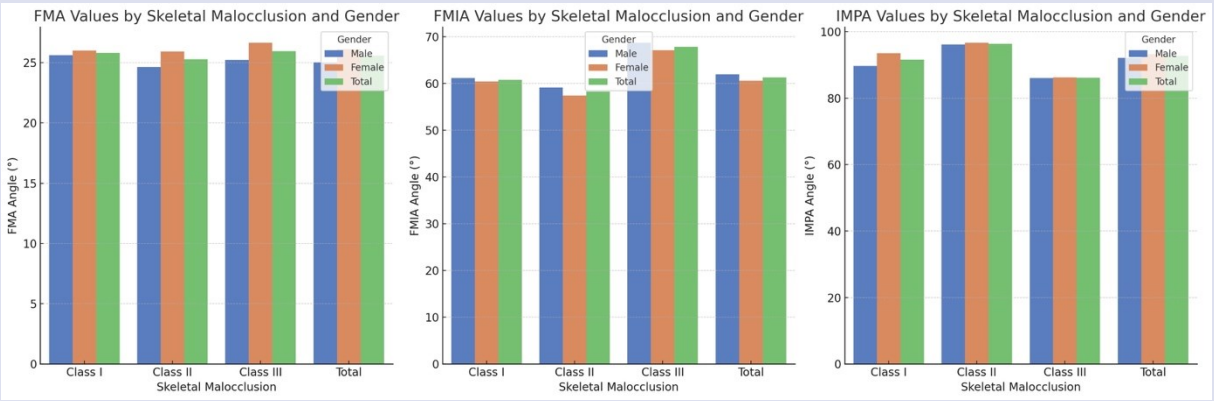

Figure 4. Descriptive statistics of FMA, FMIA, and IMPA parameters by skeletal malocclusion and gender. The bar graphs represent the mean values for each group.

Discussion

This study evaluated the relationship and differences in Tweed cephalometric analysis measurements based on malocclusion type and gender in individuals with different dental and skeletal malocclusions. Significant differences were found in IMPA and FMIA angles among dental and skeletal malocclusion groups. Additionally, reference values for Tweed cephalometric analysis in Turkish individuals were obtained. An equal number of male and female individuals were included in each group to ensure a balanced comparison. This study ensured a homogeneous age distribution across groups to minimize the potential effects of age-related variations on the findings. Since age is a critical factor influencing skeletal growth and orthodontic parameters, selecting age-matched individuals enhances the validity and reliability of the study. In the study involving adolescent individuals, hand-wrist radiography, one of the maturation indicators previously suggested in various studies,[17,19] was evaluated. Hand-wrist radiographs were used to determine skeletal maturation stages, and individuals included in the study were limited to stages 6 through 11.[17] This selection criterion was implemented to focus on individuals in the adolescent phase, during which orthodontic interventions are most performed and when skeletal changes can significantly influence treatment outcomes.[20] Accordingly, the study group was formed from adolescent individuals who receive orthodontic treatment most frequently. Previous research has shown that cephalometric measurements can vary at different stages of growth and development.[3,4] Given that Tweed cephalometric analysis parameters may change over time, including individuals within a similar age range in this study allowed for a more accurate assessment of the relationships between malocclusion and gender. Similarly, in the study by Kumari et al.,[5] the broad age range of the participants was reported as a limitation, making it difficult to draw definitive conclusions about gender differences.This highlights the significance of the age-matched selection in the present study, ensuring that the obtained results are more reliable reference values for the population. However, to further investigate the effect of growth on Tweed cephalometric analysis parameters, future research should cover a wider age range to provide a more comprehensive understanding of age-related cephalometric changes.

The findings of this study indicate that Tweed cephalometric analysis values do not differ between genders in the Turkish population. In the study by Kumari et al.,[5] differences were observed in IMPA for C-II division 1 individuals and in IMPA and FMIA for C-II division 2 individuals in a Central Indian population. However, their study included a wide age range, a limited sample size, and lacked power analysis, which may affect the validity of their conclusions. A study by Çoban et al.,[21] which focused only on skeletal malocclusion, reported findings consistent with the present study, showing no significant gender differences in IMPA angle. Similarly, Başçiftçi et al.[22] found that the ANB angle did not differ between genders in individuals with acceptable facial profiles and normal occlusion. However, their study had a single sample, used an L1/NB angle instead of IMPA, had a limited sample size, and was conducted only in adults.

In contrast, the present study focused on adolescents, a period in which orthodontic treatment is more frequently applied,[23] and malocclusion treatment is generally recommended.[24] This study categorized participants based on dental and skeletal malocclusion types to provide a more structured evaluation. On the other hand, Uysal et al.[25] found that the ANB angle differed between genders, even among individuals with well-proportioned faces and normal occlusion. These variations in the literature suggest that there is still no consensus on gender-based differences in cephalometric measurements, further highlighting the relevance and importance of the present study. When dental and skeletal malocclusion were considered, the FMA angle in Tweed cephalometric analysis did not show significant differences among malocclusion groups. Tweed reported that the normal range for FMA in individuals should be between 22° and 28°, with an average of 25°.[3,9] In the present study, the FMA angle ranged from 23° to 33°, with an average value of 25°, like Tweed's findings. The broader range of values observed in this study is likely due to the inclusion of individuals with different dental and skeletal malocclusion types. Additionally, the mean FMA value obtained falls within the normal range reported in previous studies.[3,4] Similar to our study, Nazir and Mustaq reported that FMA did not differ among malocclusion groups.[26] This finding may be attributed to the fact that individuals included in this study did not show significant differences in vertical growth patterns (as assessed by the SN/GoGn angle). A previous study indicated that FMA is related to vertical growth direction.[3] Furthermore, Ahmed et al.[27] found that SN/GoGn and FMA angles are reliable indicators for evaluating vertical growth, supporting the use of these angles in cephalometric analysis.

Tweed defined the normal FMIA angle as 65° (between 62° and 70°).[3,9] In the present study, the FMIA angle ranged from 55° to 79°, with an average value of 62°, which differs from Tweed's findings. This variation is also likely due to the inclusion of individuals with different dental and skeletal malocclusion types. Additionally, a study by Gazilerli reported that the FMIA angle in Turkish individuals is lower than the values suggested by Tweed, which supports our findings.[4] The FMIA angle showed significant differences among dental and skeletal malocclusion groups. When examined based on dental and skeletal malocclusion, C-I and C-II individuals had similar FMIA values, while C-III had significantly higher values. A recent study by Kang et al.[28] highlighted that FMIA is a valuable parameter for evaluating sagittal malocclusion, as it differs between C-I and C-II individuals, supporting the approach taken in this study. However, the discrepancy between Kang et al.'s findings and the present study might be due to the inclusion of individuals with different vertical divergence patterns in their study. A study by Kumari et al.,[5] which examined FMIA angles across different malocclusion types, reported no significant difference between C-I and C-II division 1 malocclusion, supporting our findings. However, they observed a significant difference between C-I and II division 2 malocclusions, contrasting our results. This discrepancy may be due to differences in sample size and age range in their study. Despite these findings, studies on FMIA

angle remain limited, highlighting the need for further research.

Tweed defined the normal IMPA angle as 90° (between 87° and 95°).[3,4,9] In the present study, the IMPA angle ranged from 81° to 98°, with an average value of 92°. The broad range of values observed is likely due to the inclusion of individuals with different dental and skeletal malocclusions. Additionally, a study by Gazilerli reported that the IMPA angle in Turkish individuals is higher than the values suggested by Tweed, supporting our findings.[4] The findings of this study showed that compared to C-I malocclusion individuals, both dental and skeletal C-II individuals had higher IMPA values. Skeletal C-III individuals had lower IMPA values. These results are consistent with previous studies.[5,17,25] However, the number of studies investigating IMPA differences in sagittal malocclusion is quite limited, and this study may contribute to increasing awareness in this area.

This study significantly contributes to orthodontic literature by providing essential Tweed cephalometric reference data for the Turkish population, where such norms were previously limited. Given ethnic variations in cephalometric values, these population-specific norms are crucial for accurate diagnosis and personalized, effective orthodontic care, minimizing misdiagnosis. Furthermore, this study adds to the literature by evaluating how Tweed measurements differ across malocclusion types, specifically within the Turkish population. The findings highlight clinically relevant differences in FMIA and IMPA angles, such as distinct IMPA values in C-III cases, underscoring the need for meticulous treatment planning for optimal outcomes. These results can aid clinicians in predicting treatment responses and tailoring mechanics, ultimately leading to improved patient outcomes in orthodontic treatment.

Limitations

This study has several limitations: The age range is limited (and similar distribution from groups) and primarily includes adolescents. However, since most orthodontic treatments and studies focus on adolescents, this study will likely provide relevant diagnostic insights for orthodontic applications. Differences in vertical growth direction were not examined. Future studies should include a larger sample size and evaluate both sagittal and vertical growth patterns to provide a more comprehensive analysis. This study is limited by its reliance on Angle's classification and the ANB angle for assessing malocclusion. While these are traditional and widely used methods, they may not capture the full complexity of dentofacial relationships compared to more contemporary diagnostic criteria. However, their use allows for comparison with numerous previous studies employing these classifications, and they remain clinically relevant for initial orthodontic diagnosis.

Conclusions

The number of studies on Tweed cephalometric analysis in the literature is limited. Therefore, this study is one of the few investigations examining measurement differences in this cephalometric analysis method across dental and skeletal malocclusions in the Turkish population. Additionally, the following conclusions were drawn:

- Tweed cephalometric analysis measurements do not show significant differences between genders.
- The mean FMA values obtained from the study population are consistent with the typical values defined in Tweed cephalometric analysis, whereas the mean FMIA and IMPA values differ.
- The FMA angle does not vary based on malocclusion type.
- The FMIA angle is similar in C-I and II but higher in C-III individuals. Conversely, the IMPA angle is higher in C-II individuals and lower in C-III individuals compared to C-I individuals.
- This study provides a reference sample for Tweed cephalometric analysis measurements in the Turkish population with different dental and skeletal malocclusions.

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Conflicts of Interest Statement

The authors declare no conflict of interest.

Artificial Intelligence Use

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