Investigation of Mesiodistal Angulations of Posterior Teeth in Different Vertical Malocclusions Using Panoramic Radiographs

Farklı Vertikal Maloklüzyonlarda Posterior Dişlerin Meziodistal Angulasyonlarının Panoramik Radyografiler ile İncelenmesi

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ABSTRACT

The aim of this study is to investigate the mesiodistal angulations of posterior teeth on panoramic radiographs in individuals with different types of vertical malocclusion. The GoGn-SN angle and the SGo/NMe ratio were measured on cephalometric radiographs of 120 patients. Based on these measurements, the patients were classified into three groups according to their vertical skeletal patterns: hyperdivergent, normodivergent, and hypodivergent. Using the ImageJ software, the mesiodistal angulations of the posterior teeth in both the maxilla and mandible were measured on panoramic radiographs. Statistical analysis was performed using one-way analysis of variance (ANOVA) followed by Bonferroni-corrected post-hoc tests. Significant differences in posterior tooth angulations were observed among the vertical malocclusion groups. In the maxilla, statistically significant variations were found in the right first molar, the left second premolar and first molar. In the mandible, both premolars and the left canine showed significant differences, primarily between hypodivergent and hyperdivergent individuals. Posterior teeth were more upright in hypodivergent individuals, whereas hyperdivergent individuals exhibited greater angulation values, indicating a more inclined orientation relative to the horizontal reference plane. The vertical skeletal pattern affects the angulation of posterior teeth. Therefore, vertical growth direction should be taken into consideration in orthodontic diagnosis and treatment planning, and panoramic radiographs may be utilized for this purpose.

Keywords: Panoramic radiography, Tooth angulation, Vertical malocclusion

ÖZ

Bu çalışmanın amacı, farklı vertikal iskeletsel paterne sahip bireylerde panoramik radyografiler üzerinden posterior dişlerin meziodistal angulasyonlarını incelemektir. 120 hastanın sefalometrik radyografilerinde GoGn-SN açısı ve SGo/NMe oranı ölçülmüştür. Bu ölçümler doğrultusunda hastalar hipodiverjan, normodiverjan ve hiperderverjan olmak üzere üç gruba ayrılmıştır. Posterior dişlerin maksilla ve mandibuladaki meziodistal angulasyonları panoramik radyografilerde ImageJ yazılımı kullanılarak ölçülmüştür. İstatistiksel analizde tek yönlü varyans analizi (ANOVA) ve ardından Bonferroni düzeltmeli post-hoc testler uygulanmıştır. Vertikal malokluzyon grupları arasında posterior diş açılanmalarında anlamlı farklılıklar gözlenmiştir. Maksillada, sağ birinci molar ile sol ikinci premolar ve birinci molarda istatistiksel olarak anlamlı farklar bulunmuştur. Mandibulada ise her iki premolar ile sol kaninde belirgin farklılıklar izlenmiştir. Bu farklılıklar özellikle hipodiverjan ve hiperdiverjan bireyler arasında belirgindir. Hipodiverjan bireylerde posterior dişler daha dik konumlanırken, hiperderverjan bireylerde daha fazla açılanma gözlenmiştir ve bu da dişlerin eğimli bir pozisyonda olduğunu göstermiştir. Vertikal iskeletsel patern, posterior dişlerin açılanmalarını etkilemektedir. Bu nedenle ortodontik tanı ve tedavi planlamasında dikey büyüme yönü mutlaka göz önünde bulundurulmalıdır. Panoramik radyografiler angulasyon değerlendirilmesi amacıyla kullanılabilmektedir.

Anahtar Kelimeler: Panoramik radyograf, Diş angulasyonu, Vertikal malokluzyon

Ethical approval was obtained from the Non-Interventional Ethics Committee of Ankara Medipol University (Approval number: 101).

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INTRODUCTION

Vertical malocclusions represent a significant area of concern within orthodontics and are characterized by dental and/or skeletal discrepancies in the vertical dimension. The etiology of these malocclusions is multifactorial, involving genetic predispositions, environmental influences, and individual growth patterns, all of which complicate both diagnosis and treatment.[1] Changes in facial height resulting from any etiological factor not only affect craniofacial morphology but also influence tooth eruption. In growth patterns associated with reduced facial height, both maxillary and mandibular teeth frequently exhibit mesial migration, whereas in patterns with increased facial height, tooth eruption is typically oriented in the vertical direction.[2]

Tooth angulations were described by Andrews as one of the six keys to normal occlusion.[3] In particular, the relationship between growth direction and tooth angulations has continued to be investigated in subsequent studies. One study demonstrated that molar relationships are influenced by the sagittal growth pattern of the jaws,[4] whereas the angulation of teeth reflects the dentition's adaptive response to this growth direction.[5] Considering the significant role of posterior teeth in anchorage control, their angulations should be considered as a factor that can influence not only treatment planning but also the design of orthodontic mechanics. In a study examining molar and canine angulations using panoramic radiographs, it was demonstrated that orthodontic treatment has an impact on tooth angulations.[6] Several previous studies have evaluated the effects of orthodontic treatment on tooth angulations using panoramic radiographs.[7-9] In addition, the effects of vertical growth direction on tooth inclinations have also been investigated in previous studies. Tsunori et al. reported a significant relationship between the vertical growth direction and the inclination of both the first and second molars.[10] Similarly, another study found that patients with a vertical growth pattern tend to show forward inclination of the teeth.[11] However, both studies assessed tooth inclination in the sagittal plane.

Vertical malocclusions are conventionally assessed and diagnosed using lateral cephalometric radiographs. However, in routine clinical practice—particularly in cases without sagittal discrepancies—the use of cephalometric imaging may be omitted to minimize radiation exposure. Panoramic radiographs are frequently used both pre-and post-treatment for a comprehensive dental evaluation, including the assessment of tooth angulations and occlusal relationships.[12] A previous study has identified panoramic radiographs as an effective method for evaluating the mesiodistal axial inclinations of teeth.[13]

Monitoring growth patterns is of great importance to orthodontists. In particular, the evaluation of sustained vertical growth direction should be considered when designing orthodontic appliances and planning biomechanical strategies. Conducting this assessment with panoramic radiographs offers advantages for both the patient and the clinician. Therefore, the aim of this study is to investigate the mesiodistal angulations of posterior teeth on panoramic radiographs in individuals with different vertical skeletal patterns. The null hypothesis of the study is that there are no significant differences in the mesiodistal angulations of posterior teeth among individuals with varying vertical malocclusions.

MATERIALS AND METHODS

Ethical principles of the study

Ethical approval for this study was obtained from the Non-Interventional Clinical Research Ethics Committee of Ankara Medipol University (Approval number: 101 / Approval time:22.08.2023).

Study Design

This study was designed as a retrospective cross-sectional analysis.

Sample Size Calculation

Initially, the G*Power software (version 3.1.9.7; Heinrich-Heine University, Düsseldorf, Germany) was used to determine the required sample size. Based on an effect size of f = 0.515, an alpha error of 0.05, and a power of 0.95, the minimum required sample size was calculated to be 63 patients. To ensure high statistical power and minimize the potential effects of data loss, a total of 120 radiographic records—consisting of 40 patients in each group—were included in the study after a thorough archive review conducted within the Department of Orthodontics.

Sample Selection Criteria

The inclusion criteria for this study were as follows: (1) No history of orthodontic treatment, (2) being in the permanent dentition stage, (3) presence of Class I malocclusion (ANB angle between 0° and 4°), and (4) no missing or impacted teeth, excluding third molars. The exclusion criteria were as follows: (1) being in the CV5 stage or earlier of cervical vertebral maturation, indicating ongoing growth, (2) presence of severe crowding greater than 6 mm, (3) presence of any dental anomaly, (4) presence of craniofacial anomalies such as cleft lip and/or palate, (5) presence of extensive restorations that significantly alter crown morphology, and (6) presence of artifacts on panoramic radiographs that prevent accurate assessment measurements.

Cephalometric and Panoramic Measurements

The GoGn-SN angle and the SGo/NMe ratio were measured on the patients' lateral cephalometric radiographs to determine the vertical skeletal pattern. Since the GoGn-SN angle reflects mandibular plane steepness, and the SGo/NMe ratio represents the posterior-to-anterior facial height proportion, their combined use enables a more comprehensive evaluation of the vertical skeletal morphology than using either parameter alone. The classification criteria used to categorize patients based on these measurements are provided in Table 1. Only patients who met the criteria for both measurements were included and assigned to three groups based on their vertical skeletal pattern. The demographic characteristics of the groups are summarized in Table 2.

Mesiodistal angulations of posterior teeth were measured on panoramic radiographs using ImageJ software (version 1.54g). Measurements for the maxillary posterior teeth are illustrated in Figure 1, while those for the mandibular posterior teeth are presented in Figure 2. For all measurements, the horizontal interorbital plane—defined as the line connecting the lowest points of the right and left orbital rims—was used as the reference plane. The long axis of each tooth was determined by drawing a line through the midpoint of its mesiodistal width and aligned with the path of the pulp chamber. The angle between this long axis and the reference plane was then measured.

Statistical Analyses

All statistical analyses were performed using the SPSS software package (version 23; IBM Corp., Armonk, NY, USA). The normality of data distribution was assessed using the Kolmogorov–Smirnov test. After confirming that the data followed a normal distribution ($p>0.05$), descriptive statistics were presented as mean ± standard deviation. One-way analysis of variance (ANOVA) was conducted to evaluate differences among the groups. For multiple comparisons between groups, post-hoc tests with Bonferroni correction were applied. The intraclass correlation coefficient (ICC) was used to assess the reliability of repeated measurements performed by the same observer. The ICC values for the repeated measurements ranged from 0.618 to 0.949, indicating good to excellent intra-rater reliability across all evaluated parameters. A p-value of less than 0.05 was considered statistically significant.

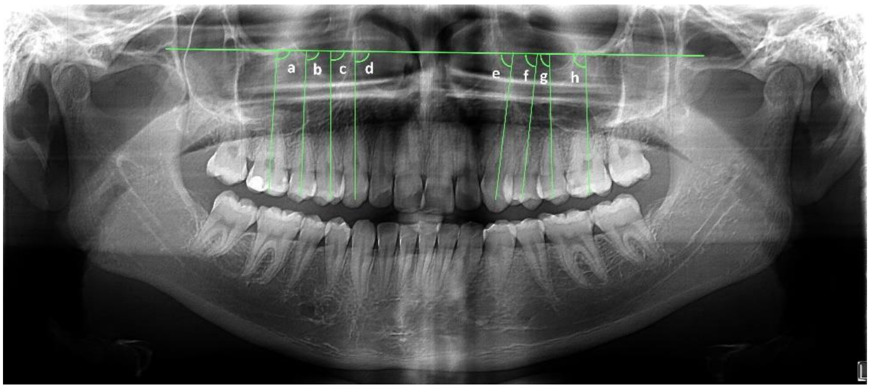

Figure 1. Panoramic radiograph showing the angulation of maxillary posterior teeth in relation to a horizontal reference plane. Green lines indicate the long axes of the maxillary posterior teeth. Angles labeled as (a) right first molar, (b) right second premolar, (c) right first premolar, (d) right canine (e) left canine, (f) left first premolar, (g) left second premolar, and (h) left first molar represent the inclination measurements relative to the horizontal plane.

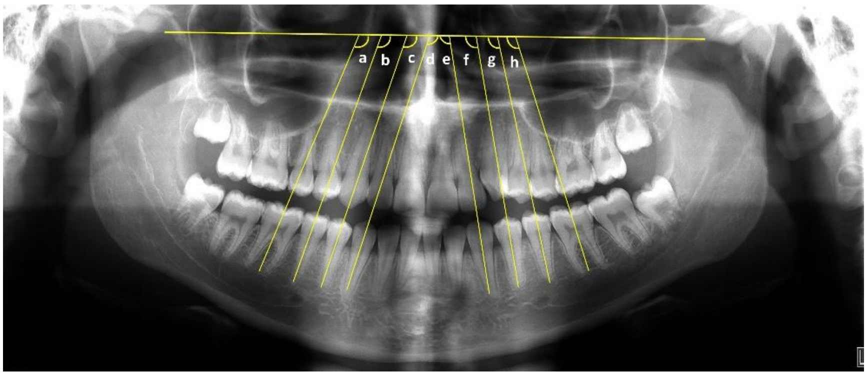

Figure 2. Panoramic radiograph showing the angulation of mandibular posterior teeth in relation to a horizontal reference plane. Yellow lines indicate the long axes of the mandibular posterior teeth. Angles labeled as (a) right first molar, (b) right second premolar, (c) right first premolar, (d) right canine (e) left canine, (f) left first premolar, (g) left second premolar, and (h) left first molar represent the inclination measurements relative to the horizontal plane.

Table 1. Classification Criteria for Vertical Skeletal Pattern

	GoGn/SN (°)	SGo/NMe ratio (%)
Hypodivergent	≤ 27.3	≥ 68
Normodivergent	27.3 – 37.7	62 - 68
Hyperdivergent	≥ 37.7	≤ 62

GoGn/SN: Angle between the mandibular plane (GoGn) and the anterior cranial base (SN); SGo/NMe: Ratio of posterior facial height (Sella–Gonion) to anterior facial height (Nasion–Menton).

Table 2. Comparison of Demographic and Cephalometric Characteristics Among Vertical Skeletal Pattern Groups

	Hypodivergent	Normodivergent	Hyperdivergent	p
Age (years)	16.88 ± 4.42	16.58 ± 3.70	16.98 ± 3.77	0.899
ANB (°)	2.82±1.82	2.84±1.46	2.72±1.80	0.030
GoGn-SN (°)	40.90±4.58	33.38±2.59	24.85±3.88	<0.001*
SGo/NMe ratio (%)	60.17±3.20	65.40±2.37	72.79±3.75	<0.001*

**p<0.001.*

ANB: The angle formed between points A, N, and B, indicating the sagittal relationship between the maxilla and mandible. GoGn/SN: Angle between the mandibular plane (GoGn) and the anterior cranial base (SN); SGo/NMe: Ratio of posterior facial height (Sella–Gonion) to anterior facial height (Nasion–Menton).

RESULTS AND DISCUSSION

Descriptive statistics are presented in Table 2. No statistically significant difference was found among the groups in terms of age (p=0.899); however, statistically significant differences were observed for the ANB angle, GoGn/SN angle, and SGo/NMe ratio (p=0.030, p<0.001, and p<0.001, respectively).

The mesiodistal angulations of all posterior teeth across the groups are shown in Table 3. In the maxilla, statistically significant differences in mesiodistal angulations were found for the right first molar, and the left second premolar and first molar. For the right first molar, significant differences were observed between the hyperdivergent and hypodivergent groups, as well as between the normodivergent and hypodivergent groups. For the teeth on the left side, differences were identified between the hyperdivergent and hypodivergent groups.

In the mandible, significant differences in mesiodistal angulations were found in the left premolars and canine, and in both premolars on the right side. These differences were primarily between the hyperdivergent and hypodivergent groups for all these teeth. Additionally, a statistically significant difference was observed between the normodivergent and hypodivergent groups for the left first premolar.

Table 3. Comparison of Mesiodistal Angulations of Posterior Teeth Among Vertical Skeletal Pattern Groups

Tooth	Hyperdivergent	Normodivergent	Hypodivergent	p	Post-hoc Comparison
16	94.57 ± 6.37	94.22 ± 5.50	90.58 ± 6.25	0.006**	1–3 (p=0.011*) 2–3 (p=0.024*)
15	93.06 ± 6.17	93.21 ± 5.00	91.23 ± 6.11	0.238	
14	87.28 ± 6.09	89.87 ± 4.86	88.48 ± 5.14	0.103	
13	89.19 ± 6.19	89.10 ± 5.28	88.67 ± 6.04	0.915	
23	90.85 ± 6.20	89.14 ± 5.31	88.72 ± 5.13	0.199	
24	89.33 ± 6.83	88.58 ± 4.72	87.66 ± 4.39	0.387	
25	93.74 ± 6.83	92.67 ± 4.82	90.55 ± 5.47	0.046*	1–3 (p=0.044*)
26	95.57 ± 7.80	92.31 ± 6.43	91.92 ± 6.49	0.039*	1–3 (p=0.049*)

Table 3. (Continued)

36	112.17 ± 7.39	109.82 ± 5.87	109.66 ± 4.74	0.126	

35	106.68 ± 6.06	104.55 ± 5.53	102.46 ± 5.57	0.006**	1–3 (p=0.004**)
34	101.29 ± 6.46	98.83 ± 6.09	94.55 ± 6.28	<0.001***	1–3 (p<0.001***) 2–3 (p=0.008**)
33	96.33 ± 8.40	94.42 ± 7.26	91.54 ± 6.22	0.016**	1–3 (p=0.013*)
43	96.44 ± 6.76	95.79 ± 5.70	94.44 ± 6.62	0.361	
44	99.94 ± 7.08	98.35 ± 6.30	95.10 ± 6.24	0.005**	1–3 (p=0.004**)
45	104.58 ± 6.55	102.58 ± 6.15	100.20 ± 6.50	0.011*	1–3 (p=0.008**)
46	110.95 ± 6.12	111.14 ± 6.58	109.40 ± 5.81	0.388	

*p<0.05, **p<0.01, ***p<0.001.

The primary goal in orthodontic treatment is always an accurate diagnosis. This initial step is essential for appropriate anchorage control and biomechanical planning, thereby enhancing the overall success of the treatment. Among all types of malocclusions, vertical malocclusions are considered particularly challenging, making their diagnosis especially critical. Therefore, the aim of this study was to compare the mesiodistal angulations of posterior teeth in individuals with different types of vertical malocclusions. Statistically significant differences in tooth angulations were observed primarily between hypodivergent and hyperdivergent individuals in both the maxilla and mandible, leading to the rejection of the null hypothesis.

Panoramic radiographs have become a cornerstone in orthodontics, serving as an essential tool for both diagnosis and treatment planning. This imaging modality provides a comprehensive view of the entire dentition and surrounding structures, offering invaluable insights for orthodontic evaluation. It facilitates the assessment of tooth angulation, stages of dental maturation, and the condition of supporting tissues, all of which are critical for effective orthodontic treatment planning and monitoring.[14] One of the key advantages of panoramic radiographs is their utility in diagnosing malocclusions and evaluating root angulations at different stages of orthodontic treatment, including before, during, and after the intervention.

In this study, only patients with Class I malocclusion and without severe crowding in either dental arch were included. As the degree of crowding increases, angular distortions caused by tooth overlap or superposition may occur. Previous studies have reported statistically significant differences in tooth angulations among different types of malocclusion.[6, 15] Therefore, patients with a single type of malocclusion were included in this study. Similarly, excluding cases with craniofacial anomalies or radiographic artifacts ensures the reliability of the data and minimizes potential confounding variables.

Mesiodistal angulation describes the tilt of a tooth along the mesial (toward the midline of the face) to distal (away from the midline of the face) axis. Hardy et al. emphasized that errors in patient positioning during radiograph acquisition can result in inaccuracies in the assessment of tooth angulations, especially in the upper and lower molars.[16] While panoramic imaging is known to be susceptible to distortions, in the present study, a standardized measurement technique was employed, cases with radiographic artifacts were excluded, and all radiographs were acquired using the same device by the same operator to ensure consistency and accuracy. Additionally, a prior study comparing mesiodistal tooth angulations obtained from cone-beam computed tomography (CBCT) and panoramic radiography found no statistically significant differences between the two imaging techniques for maxillary posterior teeth and mandibular teeth.[12]

During the development of vertical malocclusions, particular attention is typically given to the inclination of the jaws and the vertical and sagittal relationships between the incisors. However, the mechanisms underlying vertical malocclusion development also influence the eruption direction and angulations of the posterior teeth. In a lateral cephalometric study investigating tooth angulations in individuals with different vertical growth patterns, Ledesma-Peraza and Sánchez-Tito highlighted the variations in tooth angulations observed across different malocclusion types.[17] Similarly, the present study identified significant differences in posterior tooth angulations among individuals with different vertical growth patterns. While hyperdivergent and normodivergent individuals exhibited similar angulation patterns, posterior teeth in hypodivergent individuals tended to be more upright. This difference may be attributed to the effect of lower facial height on eruption direction and mandibular rotation. Consistent with the present findings, previous studies have also reported significant differences in posterior tooth angulations based on vertical skeletal patterns.[10, 11, 15, 17, 18]

Previous studies employing lateral cephalometric radiographs have investigated tooth angulations in individuals with different skeletal patterns, typically assessing maxillary teeth in relation to the palatal plane and mandibular teeth relative to the mandibular plane. While several investigations have demonstrated that maxillary teeth exhibit a mesial inclination in individuals with a hypodivergent facial pattern,[15, 17, 19] findings from Badiee et al. contradict this, indicating mesial inclinations in hyperdivergent individuals.[11] Similarly, with respect to mandibular posterior teeth, some studies have reported mesial inclinations in hypodivergent individuals,[11, 15, 19] whereas another study identified a distal inclination in this group.[17] These inconsistencies may stem from differences in the ethnic composition of study populations or variations in sample sizes. Additionally, the inclusion of individuals from different age groups in some studies may have introduced the confounding influence of dental compensation mechanisms, which should be taken into account when interpreting the results.

In the present study, the teeth that demonstrated statistically significant differences in the maxilla were the first molars and the left second premolar, while in the mandible, significant differences were observed in the first and second premolars as well as the left canine. In a study by Al-Sheakli and Ali, which examined canine tooth angulation and height, it was reported that as the proximity of the tooth to the occlusal plane increases, the tooth tends to assume a more upright position.[20] This finding supports the results of the current study, as the more upright angulations observed in hypodivergent individuals may indicate a more controlled eruption pathway and a shorter vertical distance traveled to reach the occlusal plane. When canine teeth were specifically evaluated, no statistically significant differences were found among the groups, except for the left mandibular canine. This may be attributed to the fact that canines, due to their anatomical location, are more likely to appear in distorted or angled regions of panoramic radiographs, thereby complicating accurate angulation assessment.[21]

Limitations of the study

While panoramic radiographs provide a practical and low-radiation alternative imaging method, certain limitations are associated with their use. Measurement deviations, especially in the assessment of molar angulations, may occur due to improper patient positioning, as documented in prior studies.[16,22] Therefore, ensuring precise patient positioning during image acquisition is of critical importance. In this context, artificial intelligence-based calibration systems may represent a promising solution to mitigate such limitations. Secondly, this study employed a cross-sectional design, which does not allow for the evaluation of changes in tooth angulations over time or their response to treatment. Moreover, since only individuals with Class I malocclusion were included, the generalizability of the findings to patients with different skeletal or dental patterns may be limited. Future studies are warranted to investigate the effects of various malocclusion types and orthodontic treatment protocols on posterior tooth angulations.

CONCLUSION AND RECOMMENDATIONS

It is evident that vertical growth patterns should be considered in orthodontic diagnosis and treatment planning. The present study demonstrated that posterior teeth exhibit more upright angulations in hypodivergent individuals, while posterior teeth in hyperdivergent individuals tend to show greater inclinations relative to the horizontal reference plane. These findings highlight the influence of vertical malocclusions on posterior tooth angulation, which may be relevant when planning bracket positioning, determining force vectors, and evaluating treatment mechanics. Recognizing such anatomical and positional variations can contribute to more individualized and effective orthodontic treatment strategies, potentially reducing treatment duration and minimizing the risk of complications.

Conflict of Interest Statement

The authors declare that there is no conflict of interest related to this study.

Author Contributions

IO: Conceptualization, methodology, supervision, manuscript writing. EA: Data collection, radiographic measurements, statistical analysis, manuscript drafting. TT: Literature review, data interpretation, critical revision of the manuscript. All authors have read and approved the published version of the manuscript.

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Data Availability Statement

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

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