# ASSOCIATION BETWEEN THE THREE-DIMENSIONAL INDEX AND PANORAMIC ANGULAR PARAMETERS (α AND θ ANGLES) IN IMPACTED MAXILLARY CANINES

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## ABSTRACT

**Introduction:** Impacted maxillary canines are among the most common orthodontic anomalies and often require comprehensive radiographic assessment for accurate diagnosis and treatment planning. The KPG index is a CBCT-based three-dimensional classification system used to evaluate the severity of canine impaction.

**Aim:** To assess the association between the KPG index and angular parameters (α and θ angles) in impacted maxillary canines.

**Materials and Methods:** This retrospective study included 30 patients with impacted maxillary canines treated at the Department and Clinic of Orthodontics, Faculty of Dental Medicine, University of Sarajevo. Cone-beam computed tomography (CBCT) scans and panoramic radiographs were analyzed. The KPG index was determined from CBCT images, while α and θ angles were measured on panoramic radiographs. Correlation analysis was performed to evaluate the relationship between the KPG index and angular parameters.

**Results:** The mean KPG index was 13.17 ± 7.29, the mean α angle was 32.93 ± 21.34°, and the mean θ angle was 53.87 ± 19.91°. A statistically significant moderate positive correlation was found between the KPG index and α angle ($r_s = 0.635$, $p < 0.001$). No statistically significant association was observed between the KPG index and θ angle ($r_s = -0.234$, $p = 0.206$).

**Conclusion:** The α angle showed a significant positive association with the KPG index and may represent a useful adjunctive parameter in the assessment of impacted maxillary canines. In contrast, the θ angle was not significantly associated with impaction severity. Although panoramic radiographs provide valuable diagnostic information, CBCT-based three-dimensional imaging remains the gold standard for evaluating impacted maxillary canines and supporting orthodontic treatment planning.

**Keywords:** impacted maxillary canine; KPG index; cone-beam computed tomography; panoramic radiography; orthodontic diagnosis.

## Introduction

Impaction of maxillary canines represents a common orthodontic anomaly, and, after third molars, maxillary canines are the most frequently impacted teeth in the human dentition [1]. The reported prevalence of impacted maxillary canines ranges from 0.9% to 3.3%, occurring more frequently in females and predominantly presenting with palatal localization [2].

Permanent maxillary canines play a crucial role in masticatory function, dentofacial aesthetics, occlusal harmony, and dental stability [3]. Therefore, early recognition of this condition is of great importance, as it enables more accurate diagnosis, appropriate treatment planning, and prevention of complications associated with impacted canines and their management [4].

Timely and accurate diagnosis of impacted canines is essential due to potential complications such as root resorption of adjacent teeth, cystic changes, and ankylosis of the affected tooth [5,6].

Several imaging modalities are available for the assessment of impacted canines, including panoramic radiography (PR) and cone-beam computed tomography (CBCT). Panoramic radiographs provide a two-dimensional representation of a three-dimensional structure and may therefore result in diagnostic inaccuracies caused by image distortion and superimposition of anatomical structures, which represent the major limitations of this technique [7].

The introduction of CBCT has enabled detailed three-dimensional evaluation of impacted canines, including their position, angulation, relationship with adjacent teeth, and surrounding anatomical structures. CBCT demonstrates superior diagnostic accuracy compared with conventional radiographic methods, particularly in the assessment of adjacent root resorption and surgical-orthodontic treatment planning [8].

Several classification systems and diagnostic approaches have been proposed to evaluate the severity, position, and treatment difficulty of impacted maxillary canines. Traditionally, two-dimensional methods based on panoramic radiographs have been widely used in clinical practice. These include sector analysis and angular measurements, such as the α and θ angles, which have been shown to assist in predicting canine impaction, estimating treatment difficulty, and evaluating eruption prognosis [9-11].

Furthermore, treatment difficulty indices based on panoramic radiographs have been developed to estimate the complexity of orthodontic management and expected treatment duration [12]. Classification systems such as the Yamamoto classification have also been used to describe the position and orientation of impacted teeth using panoramic radiographs [13].

Among three-dimensional classification systems, the KPG index is one of the most widely used CBCT-based methods for assessing impacted maxillary canines. The abbreviation KPG originates from the surnames of its developers, Kau, Pan, and Gallerano, who first introduced the index in 2009 as a three-dimensional classification system for canine impactions [14]. The system was subsequently validated and adopted for broader clinical application, demonstrating good reliability and reproducibility in assessing treatment difficulty and canine position [8,15].

The KPG index evaluates the position of both the canine cusp tip and root tip in three spatial dimensions (x, y, and z planes), allowing a comprehensive assessment of impaction severity. Based on the total score, impactions are classified as easy, moderate, difficult, or extremely difficult, thereby providing a more objective evaluation of treatment complexity and orthodontic management [14]. Because of its three-dimensional nature, the KPG index can identify positional characteristics that may not be adequately visualized on conventional radiographs. Consequently, CBCT-based assessment is particularly valuable in cases of severe displacement, suspected root resorption, or when detailed surgical-orthodontic treatment planning is required. However, clinicians should

carefully consider the benefits and risks of CBCT imaging before exposing patients to additional ionizing radiation [16,17].

Panoramic radiography remains the most commonly used initial imaging modality because of its lower radiation dose, lower cost, and widespread availability.

In addition to three-dimensional classification systems, angular parameters also play an important role in the diagnostic assessment of impacted canines, particularly the α and θ angles. The α angle describes the inclination of the impacted canine relative to the midline, while the θ angle provides an additional parameter for evaluating the spatial position and direction of impaction. Increased angular values have been associated with more severe impactions, greater risk of complications, and more complex orthodontic treatment [18].

Although both the KPG index and panoramic angular measurements have been extensively described individually in the literature, studies investigating their mutual relationship remain limited. To the best of our knowledge, few studies have specifically evaluated the association between CBCT-based KPG index scores and conventional panoramic angular parameters, despite their frequent use in routine orthodontic diagnostics. Determining the correlation between the KPG index and angular measurements may contribute to a more precise assessment of impaction severity and assist clinicians in establishing an accurate diagnosis and selecting the most appropriate treatment approach.

Therefore, this study aimed to evaluate the association between the KPG index and angular measurements (α and θ angles) in impacted maxillary canines.

## Materials and Methods

This retrospective study was conducted at the Department and Clinic of Orthodontics, Faculty of Dental Medicine, University of Sarajevo. The study included the analysis of 30 cone-beam computed tomography (CBCT) scans and 30 panoramic radiographs (OPG) of orthodontic patients with impacted maxillary canines. Ethical approval was obtained from the Ethics Committee under protocol number 02-3-4-17-2-2/26 dated April 10, 2026.

The database of the Department and Clinic of Orthodontics, Faculty of Dental Medicine, University of Sarajevo, was reviewed for the period from 2012 to 2026. Inclusion criteria were patients older than 11 years with impacted maxillary canines who possessed both CBCT and panoramic radiographs. Exclusion criteria included poor image quality and patients with associated pathologies or craniofacial anomalies such as syndromes, cleft lip and palate, and severe developmental abnormalities.

The following parameters were collected for each patient: KPG index score, α angle, and θ angle. Angular measurements were performed on panoramic radiographs. For α angle determination, the long axis of the impacted canine and the facial midline were used [9,10]

The facial midline was defined by a line passing through the midpoint between the maxillary central incisors and the anterior nasal spine. The maxillary occlusal plane was determined by connecting the incisal edge of the maxillary central incisor on the examined side with the mesio-buccal cusp tip of the maxillary first molar. The angle formed between the long axis of the impacted canine and the maxillary occlusal plane represented the θ angle [10, 11].

CBCT images were evaluated using the KPG index, which assesses the position of impacted canines in three spatial dimensions (x, y, and z). The index evaluates both the cusp tip and root tip positions according to their deviation from the normal eruption pathway, with each parameter scored on a scale from 0 to 5. The KPG index was originally introduced by Kau et al. in 2009 as a three-dimensional classification system for impacted maxillary canines [14].

The x-zone represents the horizontal dimension and evaluates the mesiodistal position of the canine cusp tip and root tip relative to adjacent teeth using reconstructed panoramic views from CBCT images [14]. The y-zone represents the vertical dimension

and evaluates the vertical position of the canine cusp tip and root tip relative to adjacent teeth [14]. The z-zone represents the bucco-palatal dimension and evaluates the buccolingual position of the impacted canine using axial CBCT sections [14]. Each variable was assigned a score ranging from 0 to 5.

The total KPG index score was obtained by summing the scores of the cusp tip and root tip positions in all three spatial dimensions (x, y, and z). Based on the final score, the severity of impaction was categorized according to the original KPG index classification proposed by Kau et al. [14]:
0–9 points: Easy impaction
10–14 points: Moderate impaction
15–19 points: Difficult impaction
20 points or more: Extremely difficult impaction

*Statistical Analysis*

Statistical analysis was performed using IBM SPSS Statistics software (IBM Corp., Armonk, NY, USA). Descriptive statistical methods were used to present the collected data, including mean values, standard deviations, minimum and maximum values for the KPG index, α angle, and θ angle.

The normality of data distribution was assessed using the Shapiro–Wilk test. Since the α angle did not show a normal distribution ($p < 0.05$), correlations between the KPG index and angular parameters were evaluated using Spearman's rank correlation coefficient. The strength of correlation was interpreted as weak (0.00–0.39), moderate (0.40–0.69), and strong (0.70–1.00). Statistical significance was set at $p < 0.05$.

## Results

The Shapiro–Wilk test demonstrated normal distribution for the KPG index ($p = 0.099$) and θ angle ($p = 0.305$), whereas the α angle showed a non-normal distribution ($p = 0.014$). Therefore, Spearman's rank correlation coefficient was used for correlation analysis.

The study included 30 patients with impacted maxillary canines. The mean KPG index was 13.17 ± 7.29, the mean α angle was 32.93 ± 21.34, and the mean θ angle was 53.87 ± 19.91 (Table 1).

A statistically significant moderate positive correlation was observed between the KPG index and α angle ($rs = 0.635$, $p < 0.001$). The scatter plot demonstrated a positive association between the KPG index and α angle values (Figure 1).

In contrast, no significant correlation was found between the KPG index and θ angle ($rs = -0.234$, $p = 0.206$), indicating no statistically significant association between these variables (Table 2).

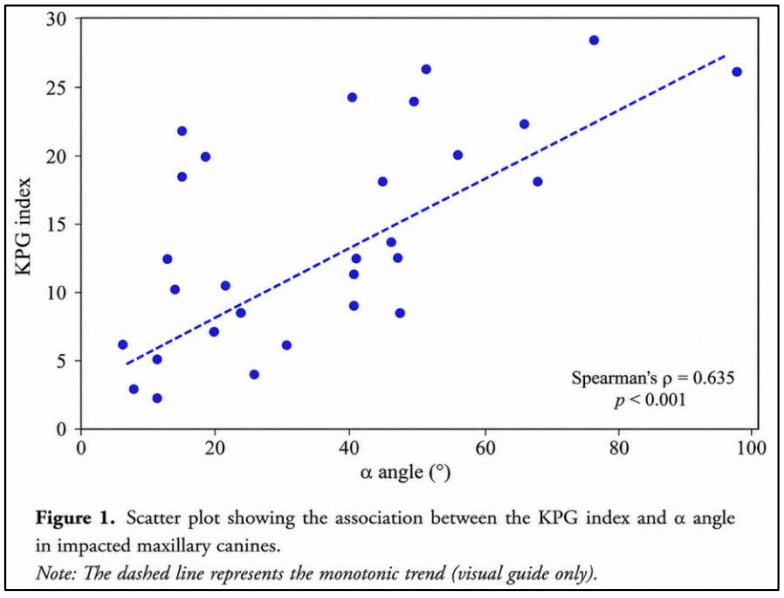


**Figure 1.** Scatter plot showing the association between the KPG index and α angle in impacted maxillary canines.
*Note: The dashed line represents the monotonic trend (visual guide only).*

**Figure 1. Correlation between the KPG index and α angle in impacted maxillary canines.**

**Table 1. Descriptive statistics of evaluated variables**

| Variable | Mean | SD | Distribution |
|---|---|---|---|
| KPG index | 13.17 | 7.29 | Normal |
| α angle (°) | 32.93 | 21.34 | Non-normal |
| θ angle (°) | 53.87 | 19.91 | Normal |

**Table 2. Correlation analysis between the KPG index and angular parameters**

| Variables | Spearman's ρ (rs) | p-value | Interpretation |
|---|---|---|---|
| KPG index vs α angle | 0.635 | <0.001 | Moderate positive correlation |
| KPG index vs θ angle | -0.234 | 0.206 | No significant correlation |

Note: Spearman's rank correlation coefficient was used because the α angle did not show a normal distribution according to the Shapiro–Wilk test.

## Discussion

The present study evaluated the association between the KPG index and angular parameters (α and θ angles) in impacted maxillary canines. The results demonstrated a statistically significant moderate positive correlation between the KPG index and α angle ($rs = 0.635$, $p < 0.001$), whereas no significant correlation was found between the KPG index and θ angle ($rs = -0.234$, $p = 0.206$).

Impacted maxillary canines represent one of the most challenging conditions in orthodontic diagnosis and treatment planning. Accurate assessment of canine position is essential because the severity of displacement directly influences treatment complexity, duration, and prognosis. The introduction of cone-beam computed tomography (CBCT) has enabled three-dimensional evaluation of impacted canines, overcoming the limitations of conventional two-dimensional radiography. Consequently, the KPG index was developed as a CBCT-based three-dimensional classification system for assessing the position and treatment difficulty of impacted maxillary canines [8]. The reliability and reproducibility of the KPG index have been confirmed in previous investigations, supporting its clinical applicability [15].

The significant positive correlation between the KPG index and the α angle observed in the present study suggests that greater canine angulation is associated with greater displacement severity. This finding is consistent with the concept that angular deviation reflects the extent to which the impacted canine differs from its normal eruption path. Previous studies have shown that increased canine angulation is frequently associated with more complicated orthodontictraction and less favorable eruption patterns [9]. Furthermore, several authors have emphasized that radiographic angular measurements can provide valuable prognostic information regarding treatment difficulty and treatment duration [19].

Nevertheless, the correlation identified in this study was moderate rather than strong, indicating that α angle alone cannot fully explain the variability in KPG scores. This observation is expected because the KPG index incorporates multiple spatial dimensions, including the position of both the crown and root in the sagittal, vertical, and transverse planes [14]. Therefore, while angular measurements provide useful information, they cannot replace a comprehensive three-dimensional assessment. Similar conclusions were reported by Dalessandri et al., who demonstrated that CBCT-based KPG evaluation offers more reliable assessment of impacted canines than conventional two-dimensional measurements alone [15].

In contrast, no statistically significant relationship was observed between the KPG index and θ angle. The weak negative correlation found in the present study suggests that θ angle may not be a reliable indicator of impaction severity. This lack of association may be explained by the fact that θ angle evaluates only a specific aspect of canine orientation and may be influenced by individual anatomical variations. Additionally, the multidimensional nature of the KPG index likely captures positional characteristics that are not adequately represented by a single angular measurement. Similar findings

have been reported in studies investigating the relationship between skeletal and positional variables and KPG scores, where certain radiographic parameters showed limited predictive value for treatment difficulty [20].

From a clinical perspective, the present findings suggest that α angle may serve as a useful adjunctive parameter during the initial assessment of impacted maxillary canines, particularly when CBCT analysis is not immediately available. However, treatment planning should not rely solely on angular measurements. Comprehensive CBCT evaluation and KPG index assessment remain essential for accurate estimation of treatment complexity and prognosis. Recent validation studies have further demonstrated that although the KPG index has good predictive value and reliability, additional factors such as patient age, root morphology, adjacent root resorption, and treatment mechanics should also be considered when determining treatment difficulty [21].

These findings are consistent with the results of the systematic review and meta-analysis by Peralta-Mamani et al. [17], which compared CBCT and panoramic radiography in the assessment of impacted maxillary canines and root resorption of adjacent teeth. The authors concluded that CBCT provides a statistically significantly more accurate evaluation of the mesiodistal and labio-palatal position of impacted canines, as well as their relationship to adjacent teeth and the presence of root resorption. Furthermore, CBCT was shown to provide clinically relevant information that may significantly contribute to diagnosis and treatment planning in cases where panoramic radiographs are insufficient. These findings further support the results of the present study and reinforce the role of three-dimensional imaging as the gold standard in the assessment of impacted maxillary canines.

The present study has several limitations. The sample size was relatively small and all patients were recruited from a single institution, which may limit the generalizability of the findings. Furthermore, the retrospective design may have introduced selection bias. Future studies, including larger multicenter samples, are warranted to further investigate the relationship between the KPG index and panoramic angular parameters.

## Conclusion

In conclusion, the results of this study demonstrated a statistically significant, moderate positive correlation between the KPG index and the α angle, indicating that greater canine angulation is associated with greater impaction severity. In contrast, the θ angle showed no significant association with the KPG index.

These findings suggest that the α angle may serve as a useful adjunctive diagnostic parameter, while the KPG index remains a comprehensive three-dimensional tool for assessing the severity of impacted maxillary canines and facilitating orthodontic treatment planning. Although panoramic radiographs (OPGs) can provide valuable information for the initial diagnosis and treatment planning of impacted maxillary canines, three-dimensional CBCT-based imaging is currently considered the gold standard, as it enables a more accurate assessment of tooth position, its relationship to adjacent anatomical structures, and potential treatment-related complications.

**Declaration of Interest:** The authors declare that they have no financial, professional, or personal interests that could have influenced the results, interpretation of data, or conclusions presented in this manuscript. The authors further declare that there is no conflict of interest related to the publication of this work.

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