ORIGINAL ARTICLE

UDC: 616.314
DOI: https://doi.org/10.2298/VSP220329010P

Evaluation of the impacted maxillary canines position, determination of the possible indicators of the impaction difficulty, and the risk factors for adjacent teeth root resorption

Procena položaja impaktiranih gornjih očnjaka, određivanje mogućih pokazatelja težine impakcije i faktora rizika od resorpcije korenova susednih zuba

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Abstract

Background/Aim. An impacted tooth is a tooth that could not erupt and take its place in the dental row. Impacted maxillary canines are a very frequent problem in orthodontic practices. They are the second most impacted teeth, right after the third molars. The aim of this cross-sectional study was to evaluate the two-dimensional and three-dimensional position of the impacted maxillary canines and make a descriptive study analysis of possible indicators of the impaction difficulty and risk factors for adjacent tooth root resorption. **Methods.** In this study, 94 subjects with 116 diagnosed maxillary canine impaction were included. The two-dimensional position of the impacted canines (IC) was evaluated on the panoramic projection of the cone beam computed tomography (CBCT) images. Canine position (CP) to the X, Y, and Z-axis was measured and scored using the novel classification system that incorporates three-dimensional information of CBCT imaging – the KPG index. Based on the KPG index value, impaction was defined as easy, moderate, difficult, and extremely difficult. In order to determine indicators of impaction difficulty and risk factors of root resorption of adjacent teeth, qualitative variables (gender, side of impaction, etc.) and quantitative variables [age, canine distance to the occlusal plane (OccP), etc.] were tested with multiple logistic regression. **Results.** The mean age of the subjects was 19.8 ± 5.2 years. The impactions were twice as prevalent in females compared to males. Most (71.4%) impactions were unilateral in palatal position of the canines. Adjacent root resorption was present in 27.3% of cases of impaction, and the central incisor was mostly affected. More than half of the impactions were of moderate level. In univariable analysis, canine distance to sagittal medial line (SML), angle between canine and SML, OccP, and first premolar, respectively, were significant in impaction difficulty prediction. Multivariable analysis showed that angle between canine and the first premolar could be a risk factor for adjacent root resorption. **Conclusion.** Most impacted maxillary canines were in the palatal position, with a KPG index value of moderate difficulty. Besides the position to the OccP and SML, angle between canine and the first premolar should be estimated, as a part of diagnostic procedures, to evaluate the risk of adjacent root resorption, prevent resorption, and decide on the treatment plan.

Key words:
cone-beam computed tomography; risk factors; tooth impacted; tooth resorption.

Apstrakt

Uvod/Cilj. Impaktirani zub je zub koji nije mogao da izbije i zauzme odgovarajuće mesto u zubnom nizu. Impaktirani maksilarni očnjaci su veoma čest problem u ortodontskoj praksi. Po učestalosti slučajeva impakcije, maksilarni očnjaci su na drugom mestu, iza umnjaka. Cilj studije preseka bio je da se proceni dvodimenzionalni i trodimenzionalni položaj impaktiranih maksilarnih očnjaka, kao i da se deskriptivnom studijom analiziraju mogući pokazatelji težine impakcije i faktori rizika od resorpcije korenova susednih zuba. **Metode.** Studijom je obuhvaćeno 94 ispitanika sa 116 impaktiranih očnjaka. Položaj očnjaka u dvodimenzionalnom sistemu ispitan je na panoramskoj projekciji snimka dobijenog metodom kompjuterizovane tomografije konusnog zraka (KTKZ). Položaj očnjaka duž X, Y i Z ose ispitan je i procenjen primenom novog sistema klasifikacije, koji uključuje trodimenzionalne informacije iz snimka KTKZ – KPG indeksa. Na osnovu vrednosti KPG indeksa, impakcija je bila ocenjena kao laka, umerena, teška i

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veoma teška. Da bi se utvrdili pokazatelji težine impakcije i faktori rizika od resorpcije korenova susednih zuba, primenom multivariacione regresije ispitivane su kvalitativne varijable (pol, strana impakcije, itd.), kao i kvantitativne varijable [životno doba, položaj očnjaka prema okluzalnoj ravni (OkR), itd.]. **Rezultati.** Prosečna starost ispitanika bila je 19,8 ± 5,2 godina. Učestalost impakcija kod žena bila je dva puta veća nego kod muškaraca. Većina (71,4%) impakcija bile su unilateralne, sa palatinalnim položajem očnjaka. Resorpcija korenova susednih zuba uočena je kod 27,3% slučajeva, a impakcijom je najčešće bio zahvaćen centralni sekutić. U više od polovine impaktiranih očnjaka težina impakcije je bila umerena. U univarijabilnoj analizi, rastojanje očnjaka od sagitalne medijalne linije (SML), nagib očnjaka prema SML i OkR, kao i nagib očnjaka prema prvom premolaru pokazali su statističku značajnost za procenu težine impakcije**.** Multivarijabilnom analizom ustanovljeno je da nagib očnjaka prema prvom premolaru može biti pokazatelj rizika od resorpcije korenova susednih zuba. **Zaključak.** Većina impaktiranih očnjaka bila je palatinalno postavljena, sa vrednostima KPG indeksa koji je ukazivao na umerenu težinu impakcije. Pored položaja očnjaka prema OkR i SML, u okviru dijagnostičkih procedura trebalo bi izmeriti i nagib očnjaka prema prvom premolaru, kako bi se procenio rizik od resoprcije korenova susednih zuba, sprečila resorpcija i odredio plan terapije.

Ključne reči:
tomografija, kompjuterizovana, konusna; faktori rizika; zub, impakcija; zub, koren, resorpcija.

Introduction

Impacted maxillary canines are very frequent in orthodontic practices. Maxillary canines are diagnosed as impacted if the eruption is delayed above the age of 14 years. They are the second most impacted teeth, right after the third molars [1, 2], due to the longest path to travel and the longest time to reach the occlusal plane compared to other permanent teeth during their development [3]. Dewel [3] has described a number of different positions in which upper canines pass in the most crowded part of the maxilla in order to reach their position in the occlusion. Since the development of the canines takes a long time, those teeth are at significant risk of negative environmental factors that can influence their eruption and cause impaction.

A recently published study reported the prevalence of the impacted maxillary canines from 1.7% to 4.7% [4]. Sexual dimorphism is also observed in the maxillary canine impaction; it affects females two to three times more frequently than males [5]. Maxillary canines could be unilaterally or bilaterally impacted; unilateral impaction appears more frequently than bilateral [4, 6, 7]. Considering the spatial position, palatally displaced canines appear more frequently compared to the buccal position [8–10]. Impacted canines (ICs) are often associated with an increased risk for adjacent tooth root resorption. The most frequently affected teeth are incisors, although, in some cases, premolars could also be affected. The prevalence of root resorption of the lateral incisors, according to the literature, ranges from 18.5% to 70% [11–13].

The position of the IC crown and root tips varies not only in the vestibulo-oral direction but also in mesio-distal and occluso-gingival directions. A precise description of the canine position (CP) in the bone in relation to local anatomical structures and distance to referent planes is essential in creating an appropriate treatment plan and treatment outcome prediction. To summarize CP in all three planes, the KPG index was proposed in 2009 [14]. The canine crown and root tip in X, Y, and Z-axis are graded based on the distance to referent planes where the crown and root tips should be properly placed. The index is the sum of these grades, and its value is used for the 3D classification of the impaction difficulty. A good level of index agreement with the clinician's evaluation of impactions was reported, so it was proposed that the KPG index could be used in orthodontic practice [15].

The use of the KPG index is particularly helpful in epidemiological investigations of the ICs. The results of these studies could help create national healthcare protocols for the early diagnosis and early management of the ICs with the appropriate scheme of preventive and interceptive measurements. The aims of this study were to evaluate the two-dimensional and three-dimensional position of the impacted maxillary canines and determine the gender distribution of the impaction, possible predictors of the impaction difficulty, and potential risk factors for adjacent tooth root resorption.

Methods

The study included 94 patients with 116 ICs treated at the Department of Orthodontics, Faculty of Dental Medicine, University of Belgrade, Serbia, referred from the primary health care centers for further diagnostics and treatment. This investigation was approved by the Ethics Committee of the Faculty of Dental Medicine, University of Belgrade, on February 22, 2017 (No. 36/4).

The inclusion criteria were patients with at least one diagnosed unerupted maxillary canine on the panoramic radiographs. The standard diagnostic procedure included clinical evaluation (intraorally, canines were not palpable labially, palatal bulge was present), study cast analysis, and radiographic analysis. On the panoramic radiograph, maxillary canines were considered impacted if more than two-thirds of tooth roots were developed, but the tooth was still totally or partially in the bone. Exclusion criteria were patients with clefts and syndromes and patients in active orthodontic treatment of impaction before and during this study. Besides panoramic radiographs, all patients that were referred to take cone beam computed tomography (CBCT) scans of the maxilla at the Radiological Center of the Faculty of Dental Medicine, University of Belgrade, were included in this study. CBCT scans were taken on the same scanner,

Cranex® 3D (Soredex, PaloDEx Group Oy Finland), in the standard resolution with a 61 x 78 cm field of view and voxel size of 0.30 mm. The scan/exposure time was 20.1/4.7 s, and the imaging value was 60kV/6.3–12.5mA. Visualization and evaluation of Digital Imaging and Communication in Medicine (DICOM) files for each patient were done in the software OnDemand3D (Cybermed Inc., South Korea). The time interval between clinical and CBCT evaluations was four to six weeks apart.

For each patient, the following parameters were collected: general data regarding the gender and age of the patient; bilateral or unilateral canine impaction; the side of the impaction in cases of unilateral impaction; the presence of the deciduous canine; space between the lateral incisor and first premolar.

The IC localization was evaluated both two-dimensionally and three-dimensionally.

The two-dimensional evaluation was done on the panoramic view of the CBCT scan, and the following measurements were included: the distance of the canine crown tip to the sagittal medial line (SML); the distance of the canine crown tip from the occlusal plane (OccP); the distance of the apex to SML; the angle between canine and SML (Figure 1); the angle between canine and OccP (Figure 1); the angle between canine and lateral incisor (Figure 2); the angle between canine and first premolar (Figure 2).

The three-dimensional evaluation was conducted in the sagittal, coronal, and axial view of the CBCT scans and included: canine mesio-distal diameter; contact with lateral incisor classified as present or absent contact; localization in the vestibulo-oral direction, which was classified as vestibular, palatal, or in the middle of the alveolar ridge; resorption of the adjacent teeth, classified as absent resorption, resorption of the lateral incisor, resorption of the central incisor, resorption of the first premolar; localization of the tooth root and crown tips along X, Y, and Z-axis according to KPG index.

Both the canine crown and root tips were evaluated by the KPG index. All measurements were performed by one examiner. One month after the first measurement, the same investigator repeated the measurements for 39 randomly selected canines. The evaluation was conducted in the X, Y, and Z spatial planes. A panoramic view of the CBCT scan was used to measure the crown and root tip position in X and Y planes (Figures 3, 4, and 5). The crown and root tip

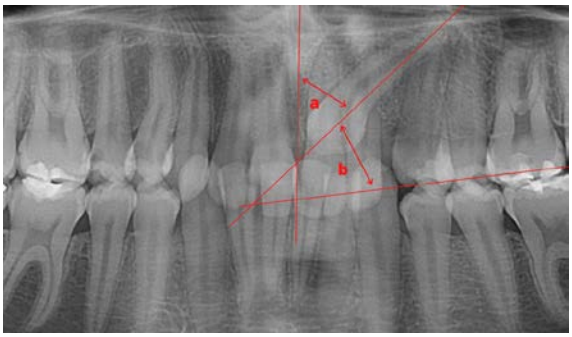

Fig. 1 – Measurements of the two-dimensional parameters on the panoramic view of the cone beam computed tomography. Red arrows annotate: a) Angle between canine and sagittal medial line; b) Angle between canine and occlusal plane.

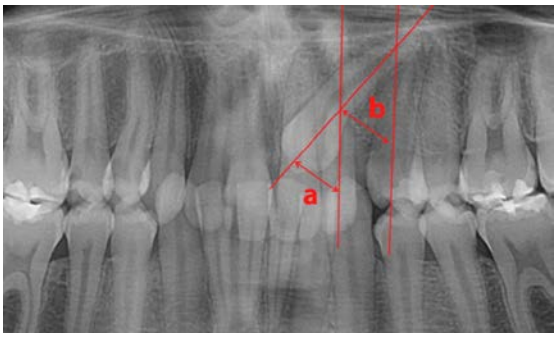

Fig. 2 – Measurements of the two-dimensional parameters on the panoramic view of the cone beam computed tomography. Red arrows annotate: a) Angle between canine and lateral incisor; b) Angle between canine and first premolar.

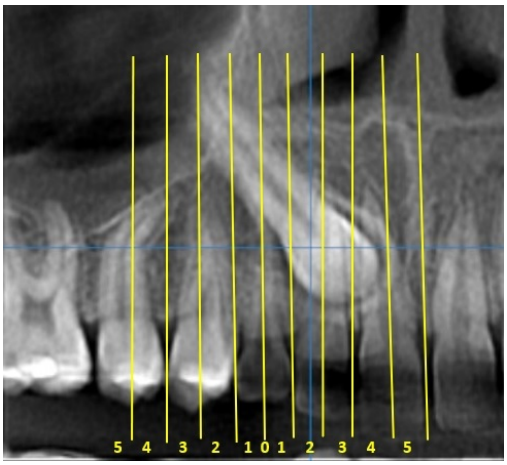

Fig. 3 – Three-dimensional evaluation of the impacted canines crown and root tip along the X-axis according to KPG index measurements. In this case, the canine crown tip was given a score of 4 and the root tip score of 2.

Fig. 4 – Canine crown tip evaluation along the Y-axis on the panoramic view of the cone beam computed tomography scan. In this patient, the canine crown tip along the Y-axis was given a score of 2.

position along the Z axis were analyzed on the axial view (Figures 6 and 7 a–d). Due to difficulties in estimating the crown and root tip position along the Z axis using the authors' [15] original scheme, in Figure 7, both the coronal and sagittal views of the crown and root position were evaluated in order to give the appropriate score. For each tooth cusp and root tip position in every coordinate plane, a score from 0–5 was given, according to deviation from their normal position. The more deviated root and crown tip position had a higher score. For every plane, there were two scores, one for the crown and one for the root tip. The sum of six scores gives a cumulative score that was used to evaluate the difficulty of the impaction. Based on the authors' definition, impaction was easy for the cumulative KPG index score 0–9, moderate for 10–14, difficult for 15–19, and extremely difficult for values 20 and above [14, 16].

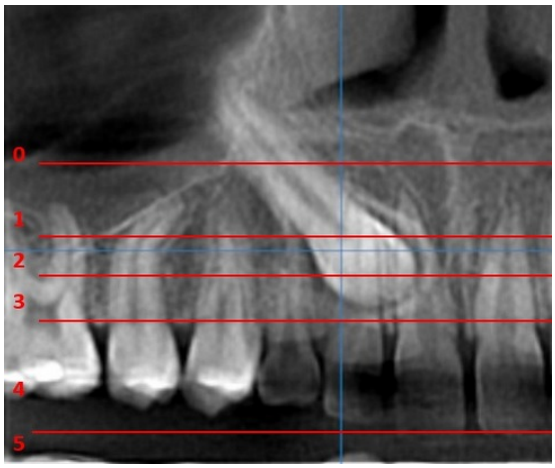

Fig. 5 – Canine root tip position along the Y-axis is graded reversed in comparison to the scores for the crown tip. For this canine root tip, the grade was 0.

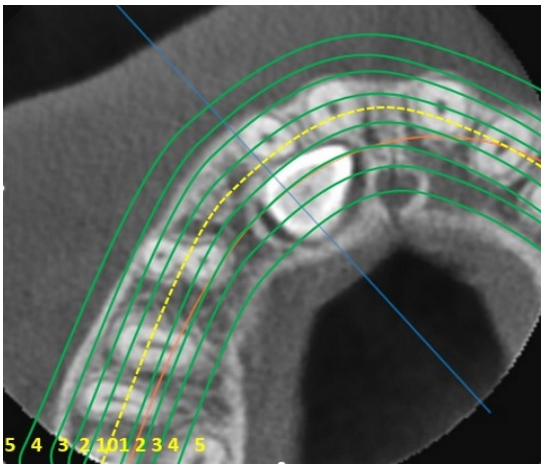

Fig. 6 – Canine crown evaluation along the Z-axis. This canine crown tip was graded a score of 2.

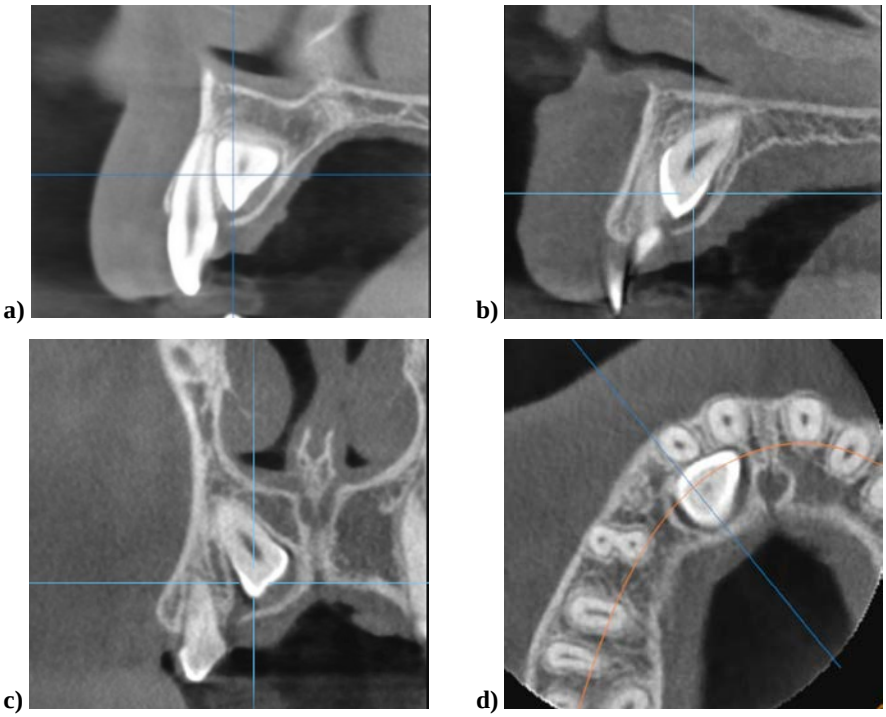

Fig. 7 – a) Sagittal position of the canine crown tip; b) Sagittal position of the canine root tip; c) Coronal view of the impacted canine; d) Axial view. Because of the difficulty to estimate the crown and root tip position along the Z-axis based on the authors' original scheme [15], besides the axial, both the coronal and sagittal view of the crown and root position were evaluated in order to give the appropriate score. For this canine crown tip, the score along the Z-axis was 2, and for the root tip, the score was 4.

Statistical analysis

Statistical analysis was performed using SPSS Version 19.0. (IBM Corp. Released 2010. IBM SPSS Statistics for Windows, Version 19.0. Armonk, NY: IBM Corp, USA). All canines were numbered and measured separately by one examiner. Distribution of the ICs by gender, age, side of the jaw, presence of deciduous canine, three-dimensional position, localization, difficulty, and contact with lateral incisor was evaluated by frequency. Descriptive statistics, such as mean and standard deviation (SD), were used for the two-dimensional quantitative variables (distance of the canine crown tip from SML, the angle between canine and SML, etc.). A total of 39 canines were randomly selected, and their KPG index was measured once again one month after the first measurement. The intra-observer reliability was evaluated with an intraclass correlation coefficient for the numerical variables, while Cohen's kappa was calculated for the categorical variables. The connection between probability for adjacent teeth resorption and investigated factors (gender, age, bilateral or unilateral impaction, size of the canine, presence of the deciduous canine, space between the lateral incisor and first premolar, two-dimensional and three-dimensional parameters) was analyzed with multiple logistic regression. Likewise, the logistic regression was conducted to test the connection between investigated factors and impaction difficulty. The results were calculated as an odds ratio with a 95% confidence interval. For all tests, the level of significance was $p < 0.05$.

Results

Intra-observer reliability for the KPG index value indicated a high agreement between first and repeated measurements. The intraclass correlation coefficient was 0.93, whereas Cohen's kappa value for the individual crown and root tips varies from 0.29 to 0.77 (Table 1). Out of 94 patients, most of the individuals were females, presented by two-thirds of the total number of subjects (Table 2). The mean patient age was 19.8 ± 5.2, so most patients were late adolescents or young adults, with canine apex closed in more than half (60.3%) of the sample. From 116 ICs, most were unilateral impactions with almost equal distribution of the left and right-side affected, and only 21 patients had bilateral impaction. Deciduous canines were extracted in 61 (58.7%) patients, which was expected based on the patient's age. The bilateral presence of deciduous canines was rare [only 12 (11.5%) patients]. The average diameter of the ICs was 7.2 mm ± 0.8 mm, with an average space for the tooth in the arch of only 3.9 mm ± 2.2 mm.

Two-dimensional parameters of the CP showed that the average canines crown tip position was 7.4 mm ± 3.3 mm and 7.3 mm ± 4.4 mm from OccP and SML, respectively (Table 3). Distance from the OccP signifies that CP in the vertical plane was not too high compared to its final position in the occlusion. The angles between canine and SML, OccP, lateral incisor, and first premolar, respectively, although with large SD, were all sharp, with the smallest value for the angle between canine and first premolar.

Three-dimensional parameters showed that most [80 (71.4%)] ICs were in the palatal position (Table 4). Most [73 (68.2%)] ICs had no contact with the lateral incisor. Furthermore, in most [72 (72.7%)] cases, resorption of the adjacent teeth was absent. In the cases where resorption of the adjacent teeth was detected, the tooth that was most affected was the central incisor, 17 (17.2%). The impaction was moderate in 62 (55.9%) cases, while 28 (25.2%) cases were difficult, 19 (17.1%) were easy, and only 2 (1.8%) were

Table 1

Results for the intra-observer reliability for the KPG index measurements

Intra-observer reliability	Crown tip X-axis	Root tip X-axis	Crown tip Y-axis	Root tip Y-axis	Crown tip Z-axis	Root tip Z-axis	KPG index value
Cohen's kappa	0.77	0.49	0.57	0.29	0.34	0.66	
Intraclass correlation coefficient							0.93

Table 2

Frequency and mean values for the first five parameters

Parameter	Values
Gender	
male	31 (33)
female	63 (67)
Age, years	19.83 ± 5.18
Side of canine impaction	
bilateral	21 (22.3)
right side	36 (38.3)
left side	37 (39.4)
Presence of the deciduous canines	
extracted	61 (58.7)
unilateral presence of deciduous canine	31 (29.8)
bilateral presence of deciduous canines	12 (11.5)
Space between lateral incisor and first premolar, mm	3.99 ± 2.17

All values are expressed as numbers (percentages) or mean ± standard deviation.

Table 3

Frequency and means for the two-dimensional parameters

Parameter	Values
Distance of the canine crown tip to SML, mm	7.32 ± 4.39
Distance of the canine crown tip from OccP, mm	7.43 ± 3.26
Distance of the apex to SML, °	20.69 ± 3.37
Angle between canine and SML, °	37.92 ±15.78
Angle between canine and OccP, °	52.24 ±19.39
Angle between canine and lateral incisor, °	43.5 ± 17.89
Angle between canine and first premolar, °	34.52 ± 6.37

All values are expressed as mean ± standard deviation.
SML – sagittal medial line; OccP – occlusal plane.

Table 4

Descriptive values for the three-dimensional parameters

Parameter	Values
Canine mesio-distal diameter, mm	7.25 ± 0.75
Contact with lateral incisor	
absent	73 (68.2)
present	34 (31.8)
Localization in the vestibulo-oral direction	
vestibular	25 (22.3)
palatal	80 (71.4)
in the middle of the alveolar ridge	7 (6.3)
Resorption of the adjacent teeth	
absent	72 (72.7)
resorption of the lateral incisor	4 (4)
resorption of the central incisor	17 (17.2)
resorption of the first premolar	6 (6.1)
Impaction difficulty	
easy	19 (17.1)
moderate	62 (55.9)
difficult	28 (25.2)
extremely difficult	2 (1.8)
KPG index average	12.55 ± 3.29

All values are expressed as numbers (percentages) except for canine mesio-distal diameter and average KPG index, which are shown as mean ± standard deviation.

extremely difficult. Each of the investigated parameters was tested separately with univariable logistic regression analysis for possible connection with probability for the adjacent tooth root resorption. Only parameters that showed $p < 0.25$ were included in the further analysis. In Table 5, there is a list of variables that were significant after simple logistic regression and were, therefore, included in the multiple logistic regression. After forward and backward logistic regression methods analysis, almost all parameters became statistically insignificant. The only parameter included in the preliminary model was the angle between the canine and the first premolar. The goodness-of-fit was analyzed with the Hosmer-Lemeshow test and confirmed that the preliminary model was the final model. Although the area under the curve (AUC) was 0.64, the 95% confidence interval was 0.50–0.78, so it had no high predictive value. According to this model, for every increase of the angle between the canine and first premolar for 1°, the odds for adjacent tooth root resorption increased by 1.04 times (Table 5).

Another multiple logistic regression was performed to test the connection between all investigated parameters and impaction difficulty. For that purpose, the first categorical scale for the impaction difficulty with four values (1 – easy, 2 – moderate, 3 – difficult, 4 – extremely difficult) was transformed into a binary scale with two outcomes (0 – easy and moderate, 1 – difficult and extremely difficult). Again, simple logistic regression was used for every single parameter to test its individual significance. Table 6 presents parameters that showed significance after simple logistic regression. Two-dimensional parameters, such as the distance of the canine crown tip to SML, the angle between canine and SML, OccP, and first premolar, respectively, were highly significant ($p < 0.01$) after univariable analysis. When these parameters were included in the multivariable analysis, forward and backward logistic regression methods did not keep the same independent variables; therefore, further multiple logistic regression could not be performed. Although the final model was not established, the individual

Table 5

Parameters included in the multivariable logistic regression to investigate possible association to adjacent tooth root resorption

Parameter	*p*	OR	95% CI for OR	
Presence of the deciduous canines				
extracted	Ref.			
unilateral presence of deciduous canine	0.05	0.28	0.08	1.02
bilateral presence of deciduous canines	0.08	0.27	0.06	1.16
Distance of the canine crown tip to SML	0.06	0.9	0.81	1.00
Distance of the canine crown tip from OccP	0.04*	1.17	1.01	1.35
Mesio-distal diameter of the lateral incisor	0.23	1.63	0.73	3.63
Angle between canine and SML	0.07	1.03	1.00	1.06
Angle between canine and first premolar	0.02*, **	1.04	1.01	1.07
KPG index	0.01*	1.24	1.05	1.45
Impaction difficulty				
easy	Ref.			
moderate	0.22	0.14	0.01	3.31
difficult	0.41	0.30	0.02	5.16
extremely difficult	0.84	0.75	0.04	13.24
Contact with lateral incisor				
absent	Ref.			
present	0.20	1.84	0.73	4.68

OR – odds ratios; CI – confidence interval; Ref. – reference category.
***p* < 0.05; ***p* – the only parameter that was included in the final model to predict adjacent tooth root resorption.**
For abbreviations, see Table 3.

Table 6

Parameters tested for the possible prediction of the impaction difficulty (outcomes of the dependent variable were 0 – easy and moderate impaction, 1 – difficult and extremely difficult impaction)

Parameter	*p*	OR	95% CI for OR	
Side of the impaction				
right	Ref.			
left	0.07	3.71	0.91	15.13
bilateral	0.23	2.40	0.58	9.98
Bilateral or unilateral canine impaction				
unilateral	Ref.			
bilateral	0.10	3.00	0.80	11.24
Distance of the canine crown tip to SML	0.00*	0.70	0.60	0.82
Distance of the canine crown tip from OccP	0.07	1.14	0.99	1.31
Space between lateral incisor and first premolar	0.05	0.81	0.66	1.00
Angle between canine and SML	0.00*	1.07	1.03	1.11
Angle between canine and lateral incisor	0.24	1.02	0.99	1.04
Angle between canine and OccP	0.00*	0.93	0.90	0.97
Angle between canine and first premolar	0.00*	1.06	1.03	1.10
Localization in the vestibulo-oral direction				
vestibular	Ref.			
palatal	0.35	0.25	0.01	4.60
in the middle of the alveolar ridge	0.28	3.29	0.38	28.75
Resorption of the adjacent teeth				
absent	Ref.			
resorption of the lateral incisor	0.69	1.57	0.17	14.42
resorption of the central incisor	0.75	1.67	0.74	37.73
resorption of the first premolar	0.07	9.17	0.86	97.69

***p* < 0.01. For abbreviations, see Table 3.**

impact of distance of the canine crown tip to SML, angle between canine and SML, OccP, and first premolar separately, was significant; hence, each of them could be interpreted as a factor with high probability prediction of the impaction difficulty.

Discussion

In this study, the canine two-dimensional and three-dimensional position was evaluated along with the gender distribution of the impaction. CP along X, Y, and Z-axis

was measured and used to determine impaction difficulty. Investigated parameters (gender, age, side of the impaction, two-dimensional and three-dimensional parameters) were tested to find potential predictors of the impaction difficulty and define the probability for adjacent tooth root resorption.

Considering the two-dimensional parameters of the impacted CP, the mean distance of the canine crown tip from the OccP was 7.4 mm ± 3.3 mm. That signifies that in the vertical plane, the IC crown tip was in line with the cervical third of the incisor root or was occlusal to the cemento-enamel junction of the incisors. Similar studies reported a higher position of the ICs, where teeth were at the middle or apical third of the incisor root [6, 17, 18]. The angle between canine and SML in the present study was 37.9° ± 15.8°. This angle corresponds to the alpha angle (inclination of the canine to the midline) in the study by Rafflenbeul et al. [17], while Naoumova and Kjellberg [19] have reported smaller values of alpha angle for unilateral and bilateral impactions.

Impaction was mostly unilateral, with almost equal affection of the right and left sides of the maxilla. Bilateral impaction was present in 22.3% of the investigated impactions. These results are consistent with recent literature findings where bilateral impactions were found in 20–25% of cases [4, 6, 20].

Subjects in this study were late adolescents or young adults. Even though the normal path of the shift in the eruption of the permanent canines was disturbed, 58.7% of the deciduous canines were absent. That could be explained by the patient's age and morphological and physiological characteristics of deciduous teeth that are not assumed to last a lifetime. Furthermore, it is possible that some of the deciduous canines were extracted as an interceptive treatment for permanent canine impaction. Still, based on the patient's age and canine root development (more than two-thirds of the root developed), even if the deciduous canines were extracted before, this could not be a confounding factor in the study since extraction has not led to a spontaneous eruption of the permanent successor.

Space for the IC was reduced in the dental arch, which was expected considering the patient's age and extraction of the deciduous canines. Although the malocclusion was not investigated in this study, the intra-arch forces direction contributing to mesial migration of the posterior teeth could be one of the reasons for this space reduction for canine placement in the upper dental arch. Migration of the teeth into extraction space was one of the side effects of the early interceptive extraction of the primary canines [19].

Findings regarding gender indicate sexual dimorphism of canine impaction since females were twice more often affected compared to males, and these results agree with findings from the literature [5, 6, 20]. Sacerdoti and Baccetti [7] have found that female-to-male prevalence of palatally displaced ICs was in a ratio of 3:1. On the contrary, some investigations reported similar prevalence among males and females [17, 18]. In the interpretation of these findings, the possibility of women seeking orthodontic treatment more often should be considered. Women appeared to be more critical in evaluating the aesthetics of the smile [21]. Likewise, younger persons are more critical in judging smiles compared to older people [22]. In our study, it could be possible that young females were more motivated to conduct orthodontic treatment; hence, it could impact the gender distribution of the sample.

The values of the KPG index for most of the teeth showed moderate impaction. When the impaction difficulty was tested in relation to the investigated parameter, the simple logistic regression showed that the distance of the canine crown tip to SML and the angle between the canine and SML, OccP, and first premolar, respectively, were highly significant. That could be interpreted in a manner that the value of each of these parameters could predict impaction difficulty. Investigating the impact of initial CP on the final treatment outcome, a systematic review has found with a low level of certainty that canine alpha angle, vertical position, and sector position influence the treatment duration and success [23].

In this study, resorption of the incisors or first premolar was detected in 27 (27.3%) cases of the investigated impactions. Most of the resorptions were diagnosed on the central incisors of the same side of the maxilla. These findings disagree with other studies, where lateral incisors were the most affected teeth [6, 8, 13, 17]. A possible explanation for our findings could be the vestibulo-oral position of the ICs. Most of the ICs were palatally displaced in the present investigation. Palatally ICs caused a reduction of the intercanine width of the upper arch. The reduced intercanine width, along with proximity to the midline and angulation of the palatally ICs, could contribute to a higher prevalence of central incisors root resorption. Multiple logistic regression analysis was used to find the model which would explain the relationship between investigated factors and the resorption of the adjacent teeth. All two and three-dimensional parameters were tested to define the factors that will best predict root resorption. The analysis has shown that the angle between the canine and the first premolar was the only predictor of probability for adjacent tooth root resorption. The test value signifies that for each angle increase of 1°, the probability for adjacent tooth root resorption increases by 1.04 times. According to Sosars et al. [24], the only parameter on the panoramic radiographs that could predict severe resorption of the incisors was the canine angle to the midline. That was with moderate predictive value based on the area under the receiver operating curve. Another study described gender, canine apex, its vertical position, and magnification as predictors of root resorption [25]. Rafflenbeul et al. [17] have described the contact between canine and adjacent teeth roots as the only possible risk factor for root resorption. The angle between the axis of the lateral incisor and the ICs is found to be in a positive relationship to lateral incisor root resorption [12]. Investigation of the incisors root resorption in the cases of palatally displaced ICs presented canine contact with lateral incisor, the presence of peg-shaped lateral incisors, and the size of the canine dental follicle as predictors of incisor root resorption [26]. Similar, severe incisor root resorption was described to be significantly associated with gender, size of the

dental follicle of the ICs, and anomalies of the lateral incisors [27]. Ericson and Kurol [28] proposed the position of the canine crown, degree of canine development, and inclination of the eruption path as factors that increased the risk for adjacent tooth root resorption. According to a systematic review, when the resorption of the incisors is detected, the most frequent is the slight resorption of the apical third of the incisor root [29].

Differences in the proposed risk factors for adjacent tooth root resorption found in the literature could be a consequence of different factors taken into consideration, particularly parameters of tooth position. Furthermore, there are differences in the statistical tests for factors evaluation and creation of the model or equation to predict possible adjacent tooth root resorption. Uribe et al. [30] used comprehensive multivariate analysis to thoroughly test multiple clinical parameters and radiographic parameters on the panoramic radiographs and cephalograms and their impact on the canine impaction prediction. The authors have not found significant predictors of canine impaction. In our study, multiple logistic regression was used to test the influence of both numerical and categorical variables to create a model that could predict tooth root resorption and impaction difficulty. The final model included the angle between the canine and the first premolar, presenting this variable as statistically significant to predict root resorption of the adjacent tooth. Considering the period when the impaction of the upper canines occurs, that is, the period of the jaw growth and completion of the permanent dentition, with the tooth eruption sequence in the maxilla, this parameter is also clinically significant. Prospective follow-up studies could help us strengthen the presented model and describe the potential model in order to define the impaction difficulty since the model for impaction difficulty could not be established in the present study.

Two-dimensional parameters were evaluated on the reconstructed panoramic image on the CBCT scans since the panoramic radiographs were not obtained from the same equipment. Even though the image is reconstructed from the specific software, it is proposed to be a more reliable tool in dental angulation analysis compared to the panoramic radiographs in the region of the canines and premolars [31]. There could be differences in the data interpretation due to the different software used for tooth position analysis [32]. Still, using this projection along with other views on the CBCT images is suggested as more reliable in precise CP analysis and adjacent root resorption compared to the panoramic radiographs [32, 33].

In the present study, the KPG index was used to evaluate the impacted CP in all three planes of space. As a 3D index, it is proposed to be helpful in the precise evaluation of the canine crown position on the CBCT scans, with a good inter-rater agreement in perceiving impaction difficulty [15, 34]. Nevertheless, it was reported that the index reliability could be influenced by using different software for visualizing the CBCT images [35]. Its clinical efficacy in treatment time and evaluation of impaction difficulty could not be confirmed based on the previous investigation [15]. Future prospective clinical trials could help in the investigation of the KPG index as a 3D index to confirm its diagnostic reliability and clinical efficacy in the evaluation of the impaction difficulty and, therefore, create a treatment plan and strategy.

Conclusion

Results of the present investigation suggest that during a comprehensive diagnostic procedure of the impacted maxillary canines, two-dimensional and three-dimensional parameters should be evaluated. In this study, most of the impactions of the maxillary canines were unilateral, palatal, and with moderate difficulty. Besides canine distance to SML and angle to SML and OccP to estimate impaction difficulty, the angle between canines and the first premolar should be given special attention since this angle could be a possible predictor of the adjacent tooth root resorption. This parameter should also be considered during patient follow-up.

Conflict of interest

The authors report no conflict of interest.

REFERENCES

1. *Al-Zoubi H, Alharbi AA, Ferguson DJ, Zafar MS*. Frequency of impacted teeth and categorization of impacted canines: A retrospective radiographic study using orthopantomograms. Eur J Dent 2017; 11(1): 117–21.
2. *Proffit WR, Fields Jr HW, Sarver DM*. Contemporary Orthodontics. 4th ed. St. Louis: Mosby; 2007.
3. *Dewel BF*. The upper cuspid: Its development and impaction. Angle Orthod 1949; 19(2): 79–90.
4. *Livgren ML, Dahl O, Uribe P, Ransjö M, Westerlund A*. Prevalence of impacted maxillary canines-an epidemiological study in a region with systematically implemented interceptive treatment. Eur J Orthod 2019; 41(5): 454–9.
5. *Becker A, Smith P, Behar R*. The incidence of anomalous maxillary lateral incisors in relation to palatally-displaced cuspids. Angle Orthod 1981; 51(1): 24–9.
6. *Grisar K, Piccart F, Al-Rimawi AS, Basso I, Politis C, Jacobs R*. Three-dimensional position of impacted maxillary canines: Prevalence, associated pathology and introduction to a new classification system. Clin Exp Dent Res 2019; 5(1): 19–25.
7. *Sacerdoti R, Baccetti T*. Dentoskeletal features associated with unilateral or bilateral palatal displacement of maxillary canines. Angle Orthod 2004; 74(6): 725–32.
8. *Lai CS, Bornstein MM, Mock L, Heuberger BM, Dietrich T, Katsaros C*. Impacted maxillary canines and root resorptions of neighbouring teeth: a radiographic analysis using cone-beam computed tomography. Eur J Orthod 2013; 35(4): 529–38.
9. *Liu DG, Zhang WL, Zhang ZY, Wu YT, Ma XC*. Localization of impacted maxillary canines and observation of adjacent incisor resorption with cone-beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2008; 105(1): 91–8.

10. *Walker L, Enciso R, Mah J.* Three-dimensional localization of maxillary canines with cone-beam computed tomography. Am J Orthod Dentofacial Orthop 2005; 128(4): 418–23.
11. *Mitsea A, Palikaraki G, Karamesinis K, Vastardis H, Gizani S, Sifakakis I.* Evaluation of Lateral Incisor Resorption Caused by Impacted Maxillary Canines Based on CBCT: A Systematic Review and Meta-Analysis. Children (Basel) 2022; 9(7): 1006.
12. *Kalavritinos M, Benetou V, Bitsanis E, Sanoudos M, Alexiou K, Tsiklakis K,* et al. Incidence of incisor root resorption associated with the position of the impacted maxillary canines: A cone-beam computed tomographic study. Am J Orthod Dentofacial Orthop 2020; 157(1): 73–9.
13. *Simić S, Nikolić P, Stanišić Zindović J, Jovanović R, Stošović Kalezić I, Djordjević A,* et al. Root Resorptions on Adjacent Teeth Associated with Impacted Maxillary Canines. Diagnostics (Basel) 2022; 12(2): 380.
14. *Kau CH, Pan P, Gallerano RL, English JD.* A novel 3D classification system for canine impactions--the KPG index. Int J Med Robot 2009; 5(3): 291–6.
15. *Kau CH, Lee JJ, Souccar NM.* The validation of a novel index assessing canine impactions. Eur J Dent 2013; 7(4): 399–404.
16. *San Martín DE, English JD, Kau CH, Gallerano RL, McGrory KR, Salas AM,* et al. The KPG index--a novel 3D classification system for maxillary canine impactions. Tex Dent J 2012; 129(3): 265–74.
17. *Rafflenbeul F, Gros CI, Lefebvre F, Bahi-Gross S, Maizeray R, Bolender Y.* Prevalence and risk factors of root resorption of adjacent teeth in maxillary canine impaction, among untreated children and adolescents. Eur J Orthod 2019; 41(5): 447–53.
18. *Jain S, Debbarma S.* Patterns and prevalence of canine anomalies in orthodontic patients. Med Pharm Rep 2019; 92(1): 72–8.
19. *Naoumova J, Kjellberg H.* The use of panoramic radiographs to decide when interceptive extraction is beneficial in children with palatally displaced canines based on a randomized clinical trial. Eur J Orthod 2018; 40(6): 565–74.
20. *Simić S, Pavlović J, Nikolić PV, Vujačić A, Vukićević V, Jovanović R.* The prevalence of peg-shaped and missing lateral incisors with maxillary impacted canines. Vojnosanit Pregl 2019; 76(1): 61–66.
21. *Bolas-Colvee B, Tarazona B, Paredes-Gallardo V, Arias-De Luxan S.* Relationship between perception of smile esthetics and orthodontic treatment in Spanish patients. PLoS One 2018; 13(8): e0201102.
22. *Pithon MM, Bastos GW, Miranda NS, Sampaio T, Ribeiro TP, Nascimento LE,* et al. Esthetic perception of black spaces between maxillary central incisors by different age groups. Am J Orthod Dentofacial Orthop 2013; 143(3): 371–5.
23. *Grisar K, Luyten J, Preda F, Martin C, Hoppenreijs T, Politis C,* et al. Interventions for impacted maxillary canines: A systematic review of the relationship between initial canine position and treatment outcome. Orthod Craniofac Res 2021; 24(2): 180–93.
24. *Sosars P, Jakobsone G, Neimane L, Mukans M.* Comparative analysis of panoramic radiography and cone-beam computed tomography in treatment planning of palatally displaced canines. Am J Orthod Dentofacial Orthop 2020; 157(5): 719–27.
25. *Alqerban A, Jacobs R, Fieuws S, Willems G.* Predictors of root resorption associated with maxillary canine impaction in panoramic images. Eur J Orthod 2016; 38(3): 292–9.
26. *Alemam AA, Abu Alhaija ES, Mortaja K, AlTawachi A.* Incisor root resorption associated with palatally displaced maxillary canines: Analysis and prediction using discriminant function analysis. Am J Orthod Dentofacial Orthop 2020; 157(1): 80–90.
27. *Chaushu S, Kaczor-Urbanowicz K, Zadurska M, Becker A.* Predisposing factors for severe incisor root resorption associated with impacted maxillary canines. Am J Orthod Dentofacial Orthop 2015; 147(1): 52–60.
28. *Ericson S, Kurol J.* Resorption of maxillary lateral incisors caused by ectopic eruption of the canines. A clinical and radiographic analysis of predisposing factors. Am J Orthod Dentofacial Orthop 1988; 94(6): 503–13.
29. *Schroder AGD, Guariza-Filho O, de Araujo CM, Ruellas AC, Tanaka OM, Porporatti A.* To what extent are impacted canines associated with root resorption of the adjacent tooth?: A systematic review with meta-analysis. J Am Dent Assoc 2018; 149(9): 765–77. e8.
30. *Uribe P, Ransjö M, Westerlund A.* Clinical predictors of maxillary canine impaction: a novel approach using multivariate analysis. Eur J Orthod 2017; 39(2): 153–60.
31. *Peck JL, Sameshima GT, Miller A, Worth P, Hatcher DC.* Mesiodistal root angulation using panoramic and cone beam CT. Angle Orthod 2007; 77(2): 206–13.
32. *Alqerban A, Jacobs R, Fieuws S, Willems G.* Comparison of two cone beam computed tomographic systems versus panoramic imaging for localization of impacted maxillary canines and detection of root resorption. Eur J Orthod 2011; 33(1): 93–102.
33. *Jung YH, Liang H, Benson BW, Flint DJ, Cho BH.* The assessment of impacted maxillary canine position with panoramic radiography and cone beam CT. Dentomaxillofac Radiol 2012; 41(5): 356–60.
34. *Dalessandri D, Migliorati M, Visconti L, Contardo L, Kau CH, Martin C.* KPG index versus OPG measurements: a comparison between 3D and 2D methods in predicting treatment duration and difficulty level for patients with impacted maxillary canines. Biomed Res Int 2014; 2014: 537620.
35. *Dalessandri D, Migliorati M, Rubiano R, Visconti L, Contardo L, Di Lenarda R,* et al. Reliability of a novel CBCT-based 3D classification system for maxillary canine impactions in orthodontics: the KPG index. Sci World J 2013; 2013: 921234.

Received on March 29, 2022
Revised on January 3, 2023
Accepted on February 3, 2023
Online First February 2023