Original Article

Factors influencing treatment duration of impacted maxillary canines

Dina Vasović[a]; Tina Pajević[b]; Ljiljana Vučić[c]; Branislav Glišić[d]; Jovana Juloski[b]

ABSTRACT

Objectives: To determine factors associated with treatment duration in impacted maxillary canines (IMCs) using orthopantomography and cone beam computed tomography.

Materials and Methods: Seventeen linear and angular measurements were evaluated using pretreatment radiographic images of 64 patients (83 IMCs). Treatment duration from surgical exposure until the canine appeared in the oral cavity and until achieving ideal alignment were recorded in months.

Results: Average treatment duration until appearance in the mouth was 14.61 ± 9.28 months and 26.98 ± 12.44 months until ideal alignment. Buccally impacted canines emerged in 6.56 ± 3.24 months and were ideally aligned in 19.44 ± 8.49 months in comparison with palatally positioned at 16.34 ± 9.19 and 28.91 ± 12.77 months, respectively. Canines localized around lateral incisors had shorter treatment times than those localized around central incisors. Canines that were inclined >30° to the sagittal medial line (SML) had significantly longer treatment time until initial appearance in the mouth (16.31 ± 9.32) compared with those inclined less (10.82 ± 8.92). Linear regression analyses demonstrated that these factors were predictors for both treatment duration until emergence and ideal alignment of the canine.

Conclusions: Treatment duration for IMCs is lengthy, particularly for palatally and mesially positioned canines and those with greater inclinations. Palatally located canines typically require twice as much time to emerge as those positioned buccally. Canines located nearer the central incisor area take twice as much time to emerge as those located in the lateral incisor area. (*Angle Orthod*. 2025;95:266–273.)

KEY WORDS: Impaction; Maxillary canines; Orthopantomography; CBCT; Treatment duration

INTRODUCTION

Impacted maxillary canines (IMCs) are the second most impacted teeth following third molars.[1] The incidence of IMCs varies across populations, ranging between 1.7% and 4.7% in the general population.[2,3]

Accurate localization of IMCs is essential and relies heavily on radiographic imaging. The most used primary diagnostic radiograph is orthopantomography (OPG), which provides two-dimensional information about canine position.[4] Initial assessment of impacted canine position on OPG before treatment initiation serves as a valuable predictor of treatment outcomes.[5] OPG cannot accurately assess the precise buccopalatal position of impacted tooth.

Cone beam computed tomography (CBCT) offers superior accuracy in determining the exact position of IMCs.[6] CBCT enables precise localization of IMCs and facilitates decision-making regarding further treatment.[7] Treatment modalities for impacted canines typically include surgical exposure followed by orthodontic extrusion or extraction.[8]

Literature on the initial localization of IMCs using OPG and CBCT and correlation with treatment duration is limited, especially for CBCT. In a systematic review, Grisar et al.[9] reported four studies that included measurements on both CBCT and OPG before the start of treatment and only one study that included buccally positioned canines. Existing evidence suggests that a palatal position, higher angle between the canine and

[a] Research Assistant, Department of Orthodontics, School of Dental Medicine, University in Belgrade, Belgrade, Serbia.
[b] Assistant Professor, Department of Orthodontics, School of Dental Medicine, University in Belgrade, Belgrade, Serbia.
[c] Instructor, Department of Orthodontics, School of Dental Medicine, University in Belgrade, Belgrade, Serbia.
[d] Full Professor, Department of Orthodontics, School of Dental Medicine, University in Belgrade, Belgrade, Serbia.
Corresponding author: Dr Jovana Juloski, Gastona Gravijea 2, Belgrade 11000, Serbia
(e-mail: jovana.juloski@stomf.bg.ac.rs)

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the sagittal medial line (SML), higher vertical position, and mesial sector location of the impacted canine are associated with less favorable interceptive and active treatment outcomes, prolonged treatment time, and inferior results.[9,10] It is crucial to inform patients about treatment success rates and anticipated duration before commencing therapy.

The aim of this study was to assess the relationship between the initial positioning of IMCs (using variables from both OPG and CBCT) with treatment duration, successful treatment outcome, or the need for extraction.

MATERIALS AND METHODS

Participants

This study was approved by the Ethics Committee of the School of Dental Medicine, University of Belgrade, on February 22, 2017 (No. 36/4). Maxillary canines were classified as impacted on OPG if more than two-thirds of the tooth root was developed while the tooth remained fully or partially covered by bone. Patients identified with IMCs on OPG underwent CBCT of the maxilla. Radiographs were taken between February 2017 and December 2022 at the Radiological Center of the School of Dental Medicine, University of Belgrade.

Inclusion criteria encompassed patients with at least one diagnosed unerupted maxillary canine who underwent treatment involving forced eruption or extraction and possessed complete diagnostic records (OPG and CBCT) along with treatment details, such as the dates of surgical exposure and ligation of a full-size stainless-steel archwire (0.016 × 0.022 inch). Exclusion criteria included patients with clefts or syndromes as well as those who missed appointments. All necessary data were extracted from diagnostic records. The study included all consecutive patients that came to the department during the research period: 64 patients with 83 impacted canines. Descriptive data are presented in Tables 1 and 2.

Radiographic Evaluation

All pretreatment measurements on OPGs and CBCTs were made by one orthodontist (D.V.). Measurements for 30 patients were done twice, 2 weeks apart, to establish intraclass correlation coefficients. Three-dimensional evaluation was done on sagittal, coronal, and axial views of the CBCT scans that were taken on the same scanner (Cranex 3D, Soredex, PaloDEx Group Oy, Finland), in the standard resolution with a 61 × 78 cm field of view and voxel size of 0.30 mm. The scan/exposure time was 20.1/4.7 seconds, and the imaging value was 60 kV/6.3–12.5 mA. Visualization and evaluation of DICOM files for each patient were done in OnDemand3D software (Cybermed Inc., South Korea). Variables measured are shown in Figures 1 through 3.[11,12]

Table 1. Descriptive Statistics for Scale Variables[a]

Parameter	Mean ± SD	Minimum	Maximum
Age (y)	15.17 ± 3.69	9	30
Lateral incisor to premolar (mm)	4.07 ± 2.07	0	8
Crown tip to SML (mm)	7.01 ± 5.14	1	30
Apex to SML (mm)	21.78 ± 4.94	13	40
Angle to SML (°)	36.89 ± 14.18	8	67
Angle to OccP (°)	46.23 ± 14.89	15	92
Angle to lateral incisor (°)	46.51 ± 18.81	4	87
Angle to premolar (°)	38.78 ± 15.46	6	84
Duration until appearance in the mouth (mo)	14.61 ± 9.28	1	35
Duration until ideal alignment (mo)	26.98 ± 12.44	3	60

[a] OccP indicates occlusal plane; SML, sagittal medial line.

Treatment

All patients underwent treatment administered by orthodontic residents under the supervision of orthodontic specialists at the University Orthodontic Department. All canines were exposed using a closed surgical technique. Orthodontic traction force was initiated approximately 7–10 days after surgical sutures were removed and was reinforced monthly thereafter. Duration until the initial appearance of the canine tip in the mouth was recorded as the period between surgical exposure and canine tip visibility in months. The duration of the forced eruption phase was defined as the interval between surgical exposure and achieving ideal alignment of IMCs, marked by ligating all teeth onto a stainless steel 0.016 × 0.022-inch archwire.

Treatment success was defined as achieving fully functional eruption of the canine without requiring additional intervention. If extraction of canines was necessary, it was noted whether the teeth were extracted at the beginning of treatment or after surgical exposure and attempted orthodontic traction. Treatment failure was determined by the extraction of the canine following unsuccessful orthodontic traction efforts.

Statistical Analysis

Statistical analysis was performed using SPSS version 19.0 (IBM Corp., Armonk, NY). Intraclass correlation for repeated measurements was excellent (0.93). Frequencies were evaluated for all investigated parameters. Descriptive statistics, such as mean and standard deviation (SD), were used for the two-dimensional quantitative variables. Independent samples *t*-test was used to determine whether gender or side of impaction influenced treatment duration. Horizontal and vertical position as well as localization on CBCT, crown tip, and

Table 2. Descriptive Statistics for Ordinal and Nominal Variables[a]

Parameter	No. (%)	*P* (χ^2 test)
Gender		<.001***
Male	18 (28.1)	
Female	46 (71.9)	
Impaction side		.881
Right	22 (48.9)	
Left	23 (51.1)	
Uni/bilateral		.001**
Unilateral	45 (70.3)	
Bilateral	19 (29.7)	
Angle classification		<.001***
Class I	43 (67.2)	
Class II	17 (26.6)	
Class III	4 (6.3)	
Vertical position		.006*
Cementoenamel junction	14 (17.7)	
Gingival third	20 (25.3)	
Middle third	32 (40.5)	
Apical third	13 (16.5)	
Horizontal position × sector		<.001***
Distal half of lateral incisor	14 (17.7)	
Mesial half of lateral incisor	21 (26.6)	
Distal half of central incisor	28 (35.4)	
Mesial half of central incisor	15 (19)	
Angle to SML		<.001***
<30°	27 (34.2)	
>30°	52 (65.8)	
Crown to OccP		<.001***
<14 mm	59 (74.7)	
>14 mm	20 (25.3)	
Contact with lateral incisor		<.001***
Yes	69 (83.1)	
No	14 (16.9)	
Localization of the crown		<.001***
Buccally	17 (20.5)	
Palatally	54 (65.1)	
In the middle of the arch	12 (14.5)	
Localization of the apex		<.001***
Buccally	7 (8.4)	
Palatally	30 (36.1)	
In the middle of the arch	46 (55.4)	
Buccopalatal position of crown tip compared to apex		<.001***
Both tip and apex buccally or palatally	22 (26.5)	
Tip is buccally, the apex is palatally and vice versa	61 (74.4)	
Inclination		<.001***
Mesial	68 (81.9)	
Vertical	8 (9.6)	
Distal	1 (1.2)	
Horizontal	6 (7.2)	
Root resorption		.002*
No resorption	28 (33.7)	
Mild	30 (36.1)	
Moderate	15 (18.1)	
Severe	10 (12)	
Orthodontic treatment decision		<.001***
Spontaneous eruption	1 (1.2)	
Orthodontic traction	68 (81.9)	
Extraction	14 (16.9)	
Treatment success		<.001***
Unsuccessful extraction	3 (4.4)	
Successful	65 (95.6)	

[a] OccP indicates occlusal plane; SML, sagittal medial line; * $P = .01$; ** $P = .001$; *** $P < .001$.

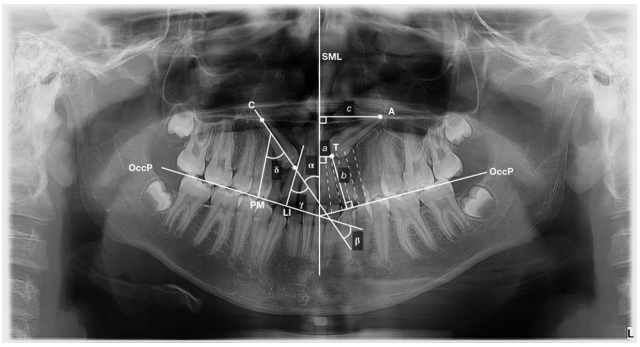

Figure 1. Reference lines: occlusal plane (OccP): traced from the mesial cusp of the maxillary first molars to the incisal margins of central incisors; sagittal medial line (SML): line connecting proximal contact point of the maxillary central incisors and anterior nasal spine; axis of impacted canine (C): connecting canine crown tip (T) and apex (A); adjacent lateral incisor (LI) and first premolar (PM). Parameters measured on orthopantomography (OPG): (1) sector by Ericson and Kurol[11]; impacted canines were classified as sector 1 to 5 based on the location of their cusp tip; (2) perpendicular distance of canine crown tip to SML (a); (3) perpendicular distance of canine crown tip from OccP (b); (4) perpendicular distance of canine apex to SML (c); (5) angle between canine and SML (α); (6) angle between canine and OccP (β); (7) angle between canine and lateral incisor (χ); (8) angle between canine and first premolar (δ); and (9) vertical position of canine cusp tip compared to adjacent teeth: cusp tip lies in a horizontal plane (i) occlusal to cementoenamel junction of incisor, (ii) with cervical third of incisor root, (iii) with middle third of incisor root, and (iv) with apical third of incisor root.

apex position were analyzed with one-way analysis of variance and independent samples *t*-test to evaluate significant effects on treatment duration. Correlations were used to explore the influence of all investigated parameters with treatment duration until appearance in the mouth and ideal alignment. Linear regression analysis was used to determine the influence of factors for which correlation was shown on treatment duration.

RESULTS

Sixty-eight impacted canines were subjected to surgical exposure and orthodontic traction, while 14 were extracted before the start of treatment. In one case, the canine erupted spontaneously, and this patient was not excluded since canines were impacted bilaterally. The overall success rate was 95.6%, since three canines were extracted after attempting orthodontic traction. Although we initially intended to also examine predictors for treatment failure, it was not possible to do statistical analyses due to the small number of failures.

It was found that approximately 14.61 ± 9.28 months was needed for IMCs to appear in the mouth and 26.98 ± 12.44 months until ideal alignment, with no difference between genders. Similar results were found for patients with different impaction sides and

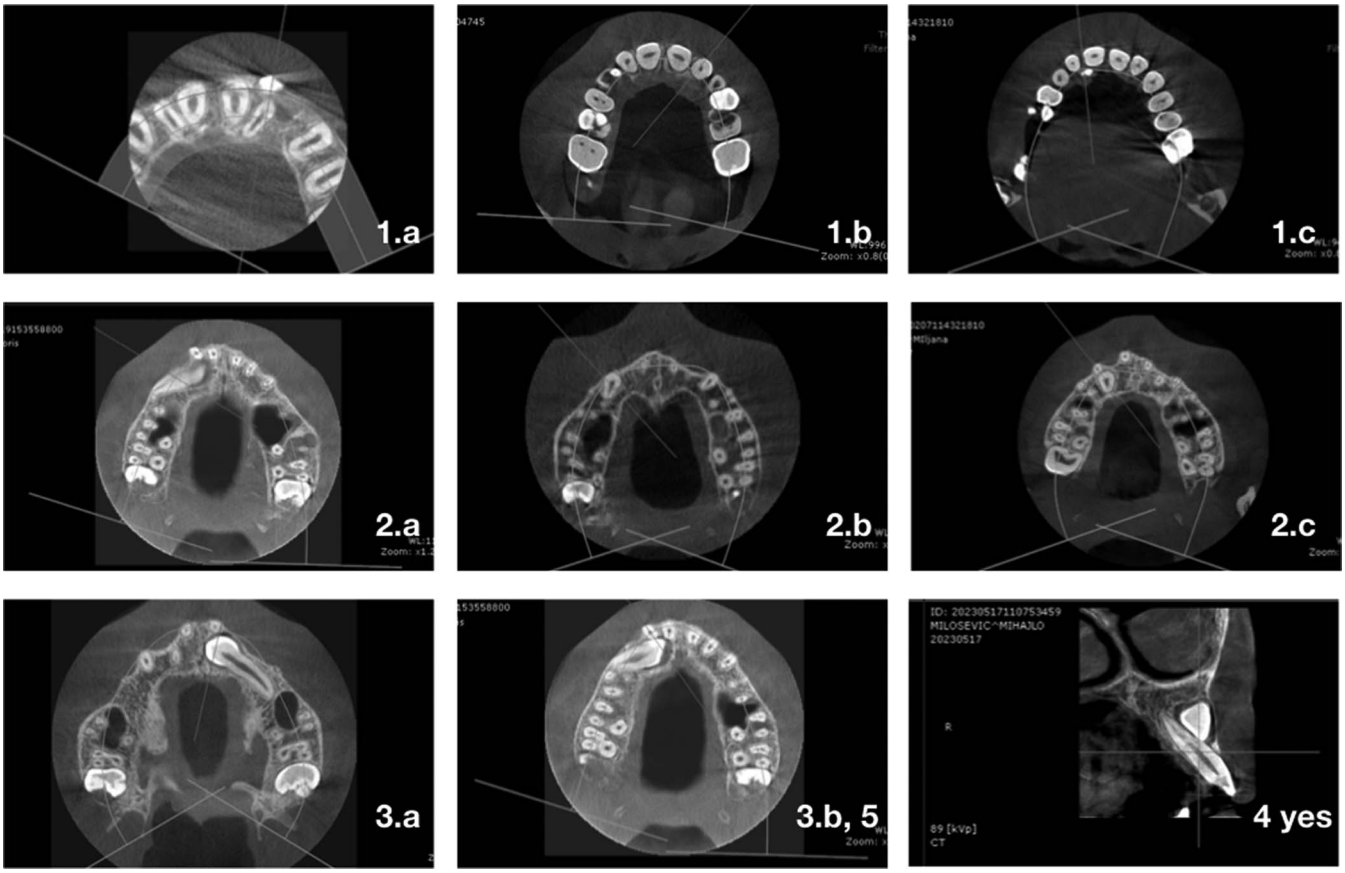

Figure 2. Parameters measured on axial view of cone beam computed tomography (CBCT): (1) buccopalatal position of crown tip compared to adjacent teeth: (a) tip buccally compared with other teeth, (b) tip in the middle of alveolar ridge, and (c) tip palatally compared with other teeth. (2) Buccopalatal position of canine apex compared to adjacent teeth: (a) apex buccally compared with other teeth, (b) apex in the middle of alveolar ridge, (c) apex palatally compared with other teeth. (3) Buccopalatal position of crown tip compared with apex: (a) both tip and apex positioned buccally or palatally, and (b) if crown tip is positioned buccally, the apex is palatally and vice versa. (4) Contact with lateral incisor (sagittal and axial views): yes/no. (5) Root resorption of adjacent teeth described by Ericson and Kurol[12] (axial, sagittal and coronal views).

with unilateral compared with bilateral impactions (Tables 3 and 4). A statistically significant difference was found between buccal and palatal crown tip position, horizontal position, and angle between the canine and SML. Canines with the crown tip located buccally had significantly shorter treatment time until initial appearance in the mouth than those with palatal and midalveolar positioning. Canines localized around lateral incisors had shorter treatment times than those localized around central incisors. Canines that were inclined $>30°$ to SML had a significantly longer treatment time until initial appearance in the mouth. Vertical position of IMCs did not significantly influence treatment duration (Tables 3 and 4).

The correlation analyses showed a statistically significant, moderate correlation between treatment duration until appearance in the mouth and the following: horizontal position, crown tip–to–SML distance (negative correlation), angle between canine and SML, and angle between canine and lateral incisor (data not shown). Linear regression revealed that horizontal position of IMCs can be a predictor for treatment duration until appearance in the mouth, and it explained 19% of the variance ($R^2 = 0.188$, $F = 13.702$, $P < .001$). Also, the parameters crown tip–to–SML distance, angle between canine and SML, and angle between canine and lateral incisor were found to be predictors, and they explained 14%, 8%, and 9% of the variance ($R^2 = 0.136$, $F = 9.289$, $P = .003$; $R^2 = 0.083$, $F = 5.353$, $P = .024$; and $R^2 = 0.087$, $F = 5.647$, $P = .021$), respectively. Multiple regression analyses did not increase the percentage of variance. Similar results were found when correlation was examined between horizontal position, crown tip–to–SML distance (negative correlation), angle between canine and SML, and treatment duration until ideal alignment. The difference was in power of prediction. A linear regression revealed that horizontal position, crown tip–to–SML distance, and angle between canine and SML could be predictors for treatment

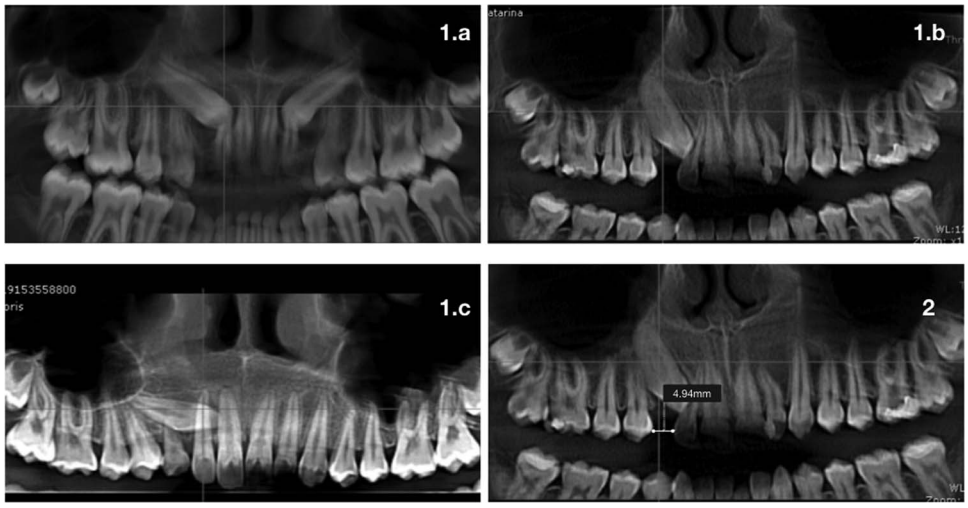

Figure 3. Parameters measured on panoramic view of cone beam computed tomography (CBCT): (1) panoramic position of an impacted tooth: (a) mesial, (b) vertical, distal, and (c) horizontal; and (2) distance between lateral incisor and first premolar measured in mm.

duration until ideal alignment with 19%, 14%, and 9% ($R^2 = 0.189$, $F = 12.813$, $P = .001$; $R^2 = 0.144$, $F = 9.272$, $P = .004$; and $R^2 = 0.090$, $F = 5.456$, $P = .023$), respectively.

DISCUSSION

The aim of this study was to evaluate radiographic parameters using both OPG and CBCT and to investigate their correlation with the treatment duration of IMCs. IMCs were more frequently observed in females, unilaterally, and in palatal positions, with both sides equally represented, consistent with general population expectations,[3,4,13] thus making the sample representative.

In the current study, we identified several OPG and CBCT factors influencing treatment duration of IMCs. Approximately 1 year of orthodontic traction was required for IMCs to emerge in the oral cavity, followed by another year for achieving ideal alignment. Factors such as patient age, gender, side of impaction, and vertical position did not exert any significant influence on treatment duration. However, longer treatment times were associated with factors such as horizontal position, buccopalatal location of the crown tip, and canine angulation.

The results showed no statistically significant association between treatment duration and patient age. While Parkin et al.[14] and Fleming et al.[15] also reported no correlation with age, Becker and Chaushu[16] and Zuccati et al.[17] found significantly longer treatment durations in adults compared with adolescents. The average age of patients was 15 years in the current study, with only 9 patients over 18 years old, suggesting age was not a decisive factor in treatment duration.

In the current study, we highlighted the significant impact of sector localization on treatment duration, indicating significantly longer orthodontic treatment time when IMCs were located near the central incisor area compared with those in the lateral incisor area. Canines positioned closer to the midline were associated with longer treatment times, suggesting sector localization as a valid indicator for treatment duration.[18–20] Fleming et al.[15] similarly suggested that a horizontal position of the canine crown relative to adjacent teeth and the midline significantly influenced treatment duration, with shorter treatment times reported for canines located in the lateral incisor or canine areas.[21]

Buccally positioned canines had significantly shorter treatment durations until they emerged in the oral cavity compared with palatally positioned canines or those situated centrally within the alveolus. While OPG may overestimate sector localization compared with CBCT scans, the clinical differences were relatively minor.[22] Given the importance of precise buccopalatal localization for treatment planning and predicting treatment duration, CBCT should be included in the diagnostic process, as supported by other studies.[23]

In the current study, we also identified that having an angle between the canine and SML $>30°$ was significantly associated with longer treatment duration until initial appearance of the canine in the oral cavity and a tendency toward longer time until ideal alignment. This angle was selected based on findings by Sajnani and King,[24] indicating that an α angle around 30° at age 9 serves was a valuable predictor for canine impaction. Power and Short[25] noted that angles $>31°$ hindered spontaneous eruption, while authors other studies have suggested that the α angle may not significantly affect treatment duration.[17,18] Stoustrup et al.[23] reported that higher angles measured in panoramic images were associated with subsequent changes in the direction of

Table 3. Factors Influencing Treatment Duration Until Appearance in the Mouth[a]

Duration Until Appearance in the Mouth, mo		*P* Value
Gender		.474[b]
Male	12.00 ± 9.23	
Female	14.29 ± 9.11	
Impaction side		.504[b]
Right	14.95 ± 10.25	
Left	12.79 ± 9.43	
Uni/bilateral		.860[b]
Unilateral	13.87 ± 9.78	
Bilateral	13.33 ± 6.24	
Vertical position		.861[c]
Cementoenamel junction	15.31 ± 13.38	
Gingival third	14.19 ± 8.99	
Middle third	14.18 ± 7.34	
Apical third	17.67 ± 7.55	
Horizontal position × sector		.001**[c]
Distal half of lateral incisor	10.45 ± 10.01 A	
Mesial half of lateral incisor	9.18 ± 6.50 A	
Distal half of central incisor	20.05 ± 8.17 B	
Mesial half of central incisor	18.69 ± 8.99 B	
Angle to SML		.041*[b]
<30°	10.82 ± 8.92	
>30°	16.31 ± 9.32	
Crown to OccP		.777[b]
<14 mm	14.96 ± 9.58	
>14 mm	14.08 ± 9.35	
Localization of the crown		.012*[c]
Buccally	6.56 ± 3.24 A	
Palatally	16.34 ± 9.19 B	
In the middle of the arch	13.50 ± 10.16 B	
Localization of the apex		.143[c]
Buccally	21.33 ± 11.00	
Palatally	14.95 ± 9.30	
In the middle of the arch	13.32 ± 8.74	
Root resorption		.598[c]
No resorption	15.14 ± 11.06	
Mild	16.13 ± 8.99	
Moderate	12.27 ± 6.13	
Severe	12.33 ± 9.04	

[a] OccP indicates occlusal plane; SML, sagittal medial line; * $P = .05$; ** $P = .01$.
[b] *t*-test.
[c] One-way analysis of variance.
A, B different small cap letters indicate statistically significant differences among groups within the same factor.

Table 4. Factors Influencing Treatment Duration Until Ideal Alignment[a]

Duration Until Ideal Alignment, mo		*P* Value
Gender		.196[b]
Male	21.60 ± 12.91	
Female	27.35 ± 12.30	
Impaction side		.881[b]
Right	25.44 ± 12.82	
Left	26.06 ± 11.26	
Uni/bilateral		.720[b]
Unilateral	25.74 ± 11.91	
Bilateral	27.25 ± 14.18	
Vertical position		.955[c]
Cementoenamel junction	28 ± 17.08	
Gingival third	26.89 ± 13.29	
Middle third	25.90 ± 9.51	
Apical third	28.8 ± 12.11	
Horizontal position × sector		.005**[c]
Distal half of lateral incisor	18.60 ± 13.23 A	
Mesial half of lateral incisor	21.31 ± 10.27 A	
Distal half of central incisor	32.47 ± 10.495 B	
Mesial half of central incisor	33.45 ± 13.14 B	
Angle to SML		.068[b]
<30°	22.29 ± 12.18	
>30°	29.03 ± 12.61	
Crown to OccP		.624[b]
<14 mm	27.40 ± 12.91	
>14 mm	25.20 ± 14.49	
Localization of the crown		.098[c]
Buccally	19.44 ± 8.49	
Palatally	28.91 ± 12.77	
In the middle of the arch	24.57 ± 11.82	
Localization of the apex		.214[c]
Buccally	34.00 ± 13.13	
Palatally	29.05 ± 15.40	
In the middle of the arch	24.92 ± 10.28	
Root resorption		.591[c]
No resorption	27.58 ± 13.72	
Mild	29.00 ± 13.15	
Moderate	22.60 ± 8.02	
Severe	25.67 ± 12.42	

[a] OccP indicates occlusal plane; SML, sagittal medial line; * $P = .05$; ** $P = .01$.
[b] *t* test.
[c] One-way analysis of variance.
A, B different small cap letters indicate statistically significant differences among groups within the same factor.

cantilever traction or considerations for canine extraction after CBCT examination.

Finally, the treatment success rate achieved was 95.6%, comparable with that of Grisar et al.,[5] who reported an orthodontically assisted eruption success rate of 96% for impacted canines.[5] Becker and Chaushu[16] noted that treatment success was influenced by patient age, with a success rate of 69.5% in patients over 30 years compared with 100% in younger individuals. Stabryła et al.[26] reported a similar 96% success rate for orthodontic traction in IMCs among patients averaging 20.6 years old. Canines categorized as moderate or difficult were successfully erupted in 100% of cases using ballista or K9 springs.[27] Only three canines required extraction in the current study due to lack of progress despite orthodontic treatment, with 14 canines deemed suitable for extraction before orthodontic treatment began. Stabryła et al.[26] initially extracted only two maxillary canines (out of 82), while Motamedi et al.[28] found that almost 20% had to be removed due to ankylosis.

CONCLUSIONS

- Treatment duration for IMCs is notably lengthy, particularly for palatally and mesially positioned canines and those with greater inclinations.

- Palatally located canines typically require twice as much time to emerge than those positioned buccally.
- Canines located nearer the central incisor area take twice as much time to emerge than those located in the lateral incisor area.

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