

Radiographic Prediction of Surgical Difficulty in Impacted Canines Using CBCT

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ABSTRACT:

Background:

Impacted maxillary canines are among the most common impacted teeth and often present considerable surgical challenges because of their variable three-dimensional position and close relationship with adjacent teeth and surrounding anatomical structures. Conventional two-dimensional radiographic techniques provide limited information regarding the exact position of impacted canines. Cone-beam computed tomography (CBCT) offers detailed three-dimensional imaging, enabling comprehensive preoperative assessment and facilitating prediction of surgical difficulty.

Aim:

To evaluate the ability of CBCT-derived radiographic parameters to predict the surgical difficulty of impacted permanent maxillary canine management.

Materials & Methods:

A retrospective observational study was conducted on CBCT images of 80 patients with impacted permanent maxillary canines requiring surgical exposure or extraction. Radiographic parameters assessed included the location of impaction, vertical position, distance from the occlusal plane, root morphology, contact with adjacent roots, external root resorption, cortical bone thickness, and follicular space width. Surgical difficulty was categorized as mild, moderate, or severe using a standardized intraoperative scoring system based on operative time, extent of bone removal, need for tooth sectioning, and intraoperative complications. Statistical analysis was performed using descriptive statistics, Chi-square test, one-way analysis of variance (ANOVA), multivariate logistic regression, and receiver operating characteristic (ROC) curve analysis. A p-value <0.05 was considered statistically significant.

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Results:

Among the 80 impacted canines, palatal impaction (61.3%) was more common than buccal impaction (38.7%), and moderate surgical difficulty was the most frequently observed category (45.0%). Cortical bone thickness, operative time, distance from the occlusal plane, and follicular space width increased significantly with increasing surgical difficulty ($p < 0.001$). Multivariate logistic regression identified impaction depth (OR=3.82, $p < 0.001$), cortical bone thickness (OR=4.16, $p < 0.001$), palatal position (OR=2.71, $p = 0.009$), and root dilaceration (OR=2.43, $p = 0.028$) as independent predictors of increased surgical difficulty. ROC analysis demonstrated that the combined prediction model had the highest diagnostic performance area under the ROC curve (AUC=0.892, sensitivity=86.5%, specificity=82.4%), outperforming individual predictors such as impaction depth (AUC=0.842) and cortical bone thickness (AUC=0.815).

Conclusion:

CBCT provides valuable three-dimensional anatomical information for predicting the surgical difficulty of impacted maxillary canine management. Greater impaction depth, increased cortical bone thickness, palatal position, and root dilaceration were identified as significant predictors of surgical complexity. Preoperative recognition of these radiographic features can improve surgical planning, facilitate risk assessment, reduce intraoperative complications, and contribute to better treatment outcomes.

Keywords: CBCT, Impacted canine, Radiographic assessment, Root morphology, Surgical difficulty

Introduction

Impacted permanent canines are among the most common eruption abnormalities encountered in dental practice, second only to impacted third molars. Their management remains a significant concern in oral and maxillofacial surgery and orthodontics because of their essential role in dental esthetics, arch stability, and functional occlusion. The prevalence of impacted canines has been reported to range between 1% and 3%, with maxillary canines demonstrating a considerably higher incidence than mandibular canines. Appropriate diagnosis and timely intervention are therefore crucial to preserve oral function and optimize treatment outcomes [1, 2].

The development of canine impaction is influenced by multiple local and systemic

factors, including hereditary predisposition, inadequate arch length, prolonged retention of deciduous canines, abnormal eruption pathways, trauma, ankylosis, supernumerary teeth, odontomas, and other developmental disturbances. Failure to diagnose and manage impacted canines at an early stage may result in several complications, such as external root resorption of adjacent teeth, follicular enlargement or cyst formation, periodontal destruction, malocclusion, pain, infection, and compromised facial esthetics. Consequently, early recognition of impacted canines is fundamental for effective treatment planning and prevention of long-term complications [3, 4].

The complexity of surgical management varies considerably among patients and is primarily

determined by the three-dimensional position of the impacted tooth and its relationship to surrounding anatomical structures. Factors including the buccopalatal position, depth of impaction, angulation, root morphology, cortical bone coverage, proximity to adjacent roots, and associated pathological changes may increase surgical difficulty. Accurate preoperative evaluation of these variables enables clinicians to anticipate operative challenges, select the most appropriate surgical approach, reduce intraoperative complications, and provide realistic information regarding treatment outcomes [5].

For many years, panoramic and periapical radiographs have served as the standard imaging modalities for assessing impacted canines. However, these two-dimensional techniques are affected by image magnification, geometric distortion, and superimposition of adjacent anatomical structures, limiting their ability to accurately determine the exact location and orientation of impacted teeth. Such limitations may compromise surgical planning, particularly in cases involving complex impactions or close proximity to adjacent roots [6].

Cone-beam computed tomography (CBCT) has transformed the radiographic assessment of impacted teeth by providing detailed three-dimensional images with substantially lower radiation exposure than conventional computed tomography. It facilitates comprehensive evaluation of the exact position of the impacted canine, root configuration, follicular dimensions, cortical bone thickness, root resorption of neighboring teeth, and anatomical relationships with structures such as the nasal floor and maxillary sinus. This detailed information enhances diagnostic accuracy, improves surgical planning, and contributes to more predictable clinical outcomes [7, 8].

Although CBCT has become an indispensable imaging tool for evaluating impacted canines, there is still limited evidence regarding the specific radiographic variables that independently predict surgical difficulty. Establishing reliable CBCT-based predictors of

operative complexity could improve preoperative risk assessment, assist surgeons in selecting appropriate treatment strategies, facilitate patient counseling, and minimize surgical complications [9]. Therefore, the present retrospective observational study was designed to investigate the association between CBCT-derived radiographic characteristics and the surgical difficulty of impacted permanent canines, identify independent predictors of surgical complexity using multivariate analysis, and evaluate the diagnostic performance of these predictors through receiver operating characteristic (ROC) curve analysis.

Materials and Methods:

Study Design:

A retrospective observational investigation was undertaken to evaluate the usefulness of CBCT in predicting the surgical difficulty associated with impacted permanent canines. All patient records were anonymized to maintain confidentiality.

Study Population:

The study included 80 patients with a single impacted permanent canine who had undergone CBCT examination before surgical treatment.

Inclusion Criteria:

- Patients between 15 and 40 years of age
- Presence of one impacted permanent canine requiring surgical intervention
- High-quality CBCT scans suitable for detailed analysis
- Complete clinical, radiographic, and surgical records
- Patients managed by surgical exposure or surgical extraction

Exclusion Criteria:

- Previous orthodontic traction of the impacted canine
- Craniofacial anomalies, including cleft lip and palate
- Cystic or neoplastic lesions associated with the impacted tooth

- Previous maxillofacial trauma affecting the canine region
- CBCT scans with artifacts or inadequate image quality

CBCT Evaluation

All CBCT datasets were independently examined by two experienced oral and maxillofacial radiologists using standardized viewing conditions

The following radiographic characteristics were recorded:

- Buccal or palatal location of the impacted canine
- Vertical position
- Depth of impaction
- Mesiodistal angulation
- Distance from the occlusal plane
- Degree of overlap with adjacent incisors
- Follicular space dimensions
- Root morphology and stage of development
- Presence of root dilaceration
- Cortical bone thickness covering the impacted tooth
- Contact with adjacent roots
- Presence of external root resorption of neighboring teeth
- Relationship to the nasal floor and maxillary sinus

Assessment of Surgical Difficulty

Surgical complexity was determined intraoperatively using a standardized scoring system based on:

- Total operative time
- Extent of bone removal
- Requirement for odontotomy or tooth sectioning
- Difficulty during luxation and delivery of the tooth
- Occurrence of intraoperative complications

Based on the cumulative score, procedures were categorized as:

- Mild difficulty
- Moderate difficulty
- Severe difficulty
- Observer Reliability

To evaluate measurement consistency, 20 randomly selected CBCT scans were re-evaluated after a two-week interval. Intraobserver and interobserver agreement were assessed using Cohen's kappa coefficient for categorical variables and the intraclass correlation coefficient (ICC) for continuous measurements.

Statistical Analysis

All statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS) Statistics software version 27.0 (IBM Corp., Armonk, NY, USA). The level of statistical significance was set at $p < 0.05$.

Descriptive statistics were used to summarize the study variables. Categorical variables, including age group, gender, location of impacted canine, side of impaction, vertical position, root morphology, contact with adjacent roots, external root resorption, and surgical difficulty, were expressed as frequencies and percentages. Continuous variables such as cortical bone thickness, operative time, distance from the occlusal plane, and follicular space width were summarized using mean, standard deviation (SD), standard error (SE), and 95% confidence intervals (CI) where appropriate.

The normality of continuous variables was assessed using the Shapiro–Wilk test. As the data demonstrated an approximately normal distribution, one-way analysis of variance (ANOVA) was used to compare the mean values of cortical bone thickness, operative time, distance from the occlusal plane, and follicular space width among the three surgical difficulty groups (mild, moderate, and severe). When statistically significant differences were identified, Tukey's post hoc test was performed for pairwise comparisons.

To identify independent predictors of surgical difficulty, binary logistic regression analysis was performed. Variables showing clinical relevance

or statistical significance in univariate analysis were entered into the regression model. The strength of association was expressed as odds ratios (ORs) with 95% CIs.

The diagnostic performance of significant predictors and the combined prediction model was evaluated using ROC curve analysis. The area under the ROC curve (AUC) was calculated to determine discriminative ability, while optimal cut-off values were identified using the Youden Index. Sensitivity and specificity were calculated for each predictor and the combined model.

All statistical tests were two-tailed, and p-values less than 0.05 were considered statistically significant. The results were presented in tables

and appropriate graphical formats to facilitate interpretation.

Results

Table 1 & Figure 1 present the age-wise distribution of the study participants. A total of 80 subjects were enrolled in the study. The largest proportion of participants was in the 21–30 years age group (38 participants; 47.5%), followed by the 31–40 years age group (22 participants; 27.5%). The 15–20 years age group included 20 participants (25.0%). Overall, individuals aged 21–30 years constituted the highest percentage of the study population, accounting for nearly half of all participants.

Table 1: Age Distribution of Study Subjects

Age Group	n	%
15–20	20	25.0
21–30	38	47.5
31–40	22	27.5
Total	80	100.0

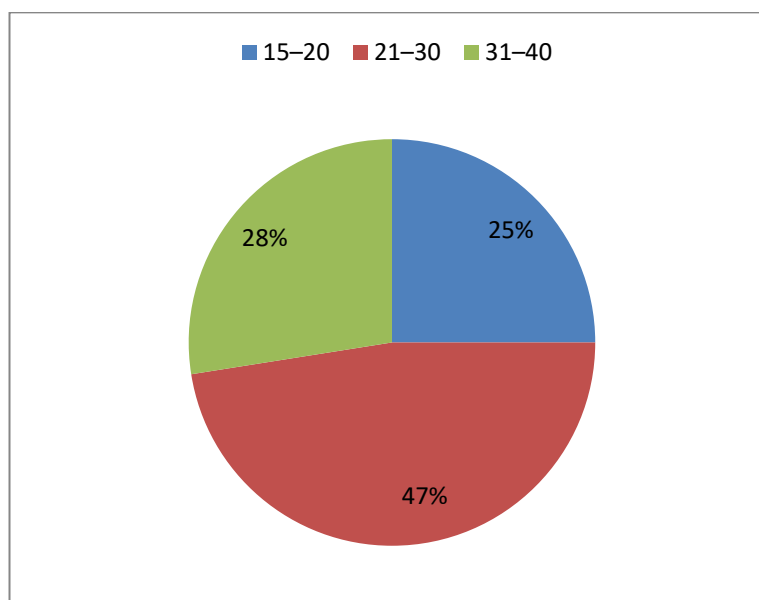


Figure 1: Age-wise Distribution of the Study Participants

Table 2 & Figure 2 illustrate the gender distribution of the study participants. Among the 80 subjects included in the study, 44 (55.0%) were female and 36 (45.0%) were male. Females represented a slightly greater proportion of the

study population than males, resulting in a female-to-male ratio of approximately 1.2:1. These findings demonstrate a modest predominance of female participants in the study sample.

Table 2: Gender Distribution of Study Subjects

Gender	n	%
Male	36	45.0
Female	44	55.0
Total	80	100.0

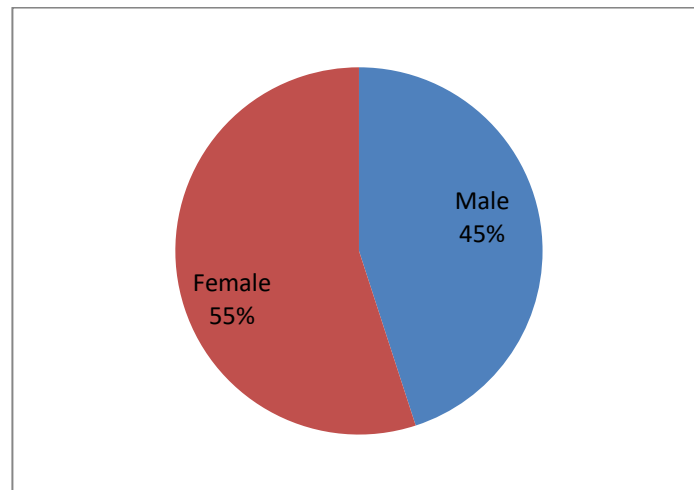
**Figure 2: Gender Distribution of the Study Participants**

Table 3 & Figure 3 present the distribution of impacted maxillary canines according to their location. Of the 80 impacted canines evaluated, 49 (61.3%) were located on the palatal side, while 31 (38.7%) were positioned buccally. Palatal impactions were more frequently observed than buccal impactions, representing nearly two-thirds of all cases included in the study.

Table 3: Location Distribution of Study Subjects

Location	n	%
Palatal	49	61.3
Buccal	31	38.7
Total	80	100.0

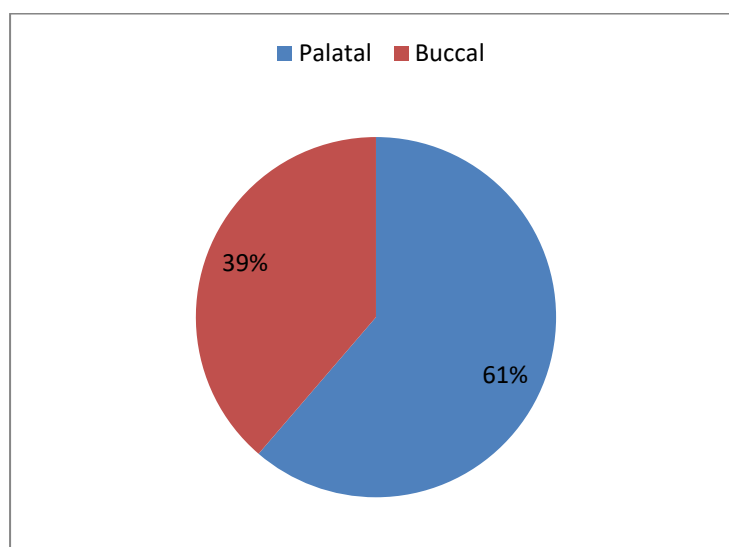
**Figure 3: Distribution of Impacted Maxillary Canines According to Location**

Table 4 & Figure 4 present the side-wise distribution of impacted maxillary canines. Of the 80 impacted canines assessed, 42 (52.5%) were located on the right side, whereas 38 (47.5%) were found on the left side. Although a

slightly greater number of impactions occurred on the right side, the overall distribution was nearly equal between the two sides, suggesting no clear side preference in the study population.

Table 4: Distribution based on Side of Impacted Canine

Side	n	%
Right	42	52.5
Left	38	47.5

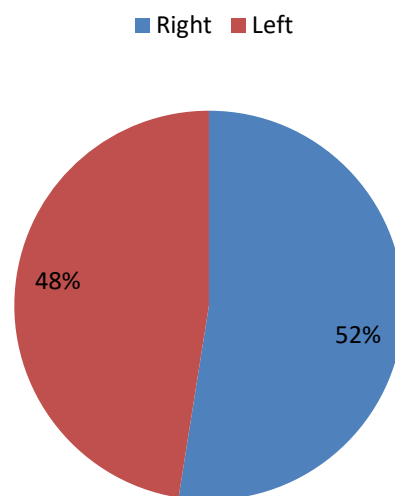


Figure 4: Side-wise Distribution of Impacted Maxillary Canines

Table 5 & Figure 5 present the distribution of impacted maxillary canines according to their vertical position. The middle third was the most frequently observed level of impaction, accounting for 36 cases (45.0%). The apical third was identified in 26 cases (32.5%), whereas

the coronal third was the least common, with 18 cases (22.5%). These findings indicate that the middle third was the predominant vertical position of impacted canines in the study population.

Table 5: Distribution based on Vertical Position of Impacted Canine

Position	n	%
Coronal third	18	22.5
Middle third	36	45.0
Apical third	26	32.5

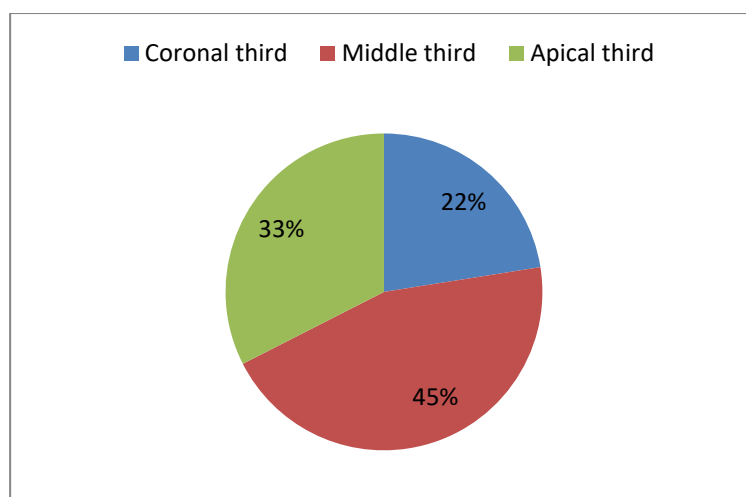


Figure 5: Distribution of Impacted Maxillary Canines According to Vertical Position

Table 6 & Figure 6 present the distribution of root morphology among the impacted maxillary canines. Normal root morphology was observed in 58 cases (72.5%), making it the most common finding. Curved roots were identified in 16 cases (20.0%), whereas root dilaceration

was noted in only 6 cases (7.5%). Overall, the results indicate that the majority of impacted canines had normal root morphology, while root deformities, particularly dilaceration, were relatively uncommon in the study population.

Table 6: Distribution Based on Root Morphology

Root Morphology	n	%
Normal	58	72.5
Curved	16	20.0
Dilacerated	6	7.5

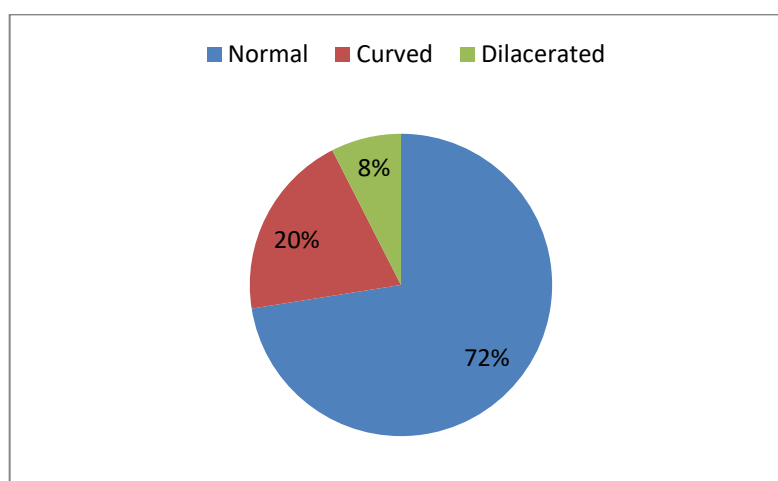


Figure 6: Distribution of Root Morphology of Impacted Maxillary Canines

Table 7 & Figure 7 present the distribution of contact between impacted maxillary canines and adjacent tooth roots. Contact with adjacent roots was observed in 34 cases (42.5%), whereas 46 cases (57.5%) showed no evidence of root contact. The absence of contact was more

frequently observed than the presence of contact. Overall, these findings indicate that although a considerable proportion of impacted canines were in contact with adjacent tooth roots, most cases did not demonstrate direct root proximity.

Table 7: Distribution Based on Contact with Adjacent Roots

Contact	n	%
Present	34	42.5
Absent	46	57.5

■ Present ■ Absent

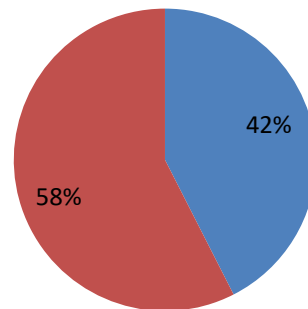
**Figure 7: Distribution of Contact Between Impacted Maxillary Canines and Adjacent Tooth Roots**

Table 8 & Figure 8 present the distribution of external root resorption associated with impacted maxillary canines. External root resorption was detected in 21 cases (26.3%), while 59 cases (73.7%) showed no evidence of resorption. The absence of external root

resorption was therefore the more common finding. Overall, these results indicate that external root resorption occurred in approximately one-quarter of the cases and was relatively infrequent in the study population.

Table 8: Distribution Based on External Root Resorption

Root Resorption	n	%
Present	21	26.3
Absent	59	73.7

■ Present ■ Absent

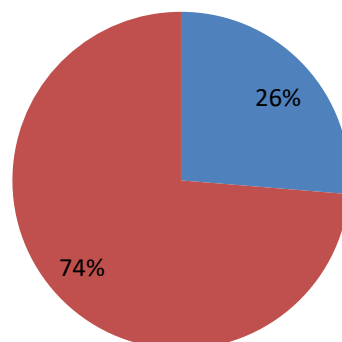
**Figure 8: Distribution of External Root Resorption Associated with Impacted Maxillary Canines**

Table 9 & Figure 9 present the distribution of surgical difficulty among the impacted maxillary canines. Moderate surgical difficulty was the most frequently observed category, accounting for 36 cases (45.0%). Mild surgical difficulty was recorded in 24 cases (30.0%), while severe

surgical difficulty was identified in 20 cases (25.0%). These findings indicate that moderate surgical difficulty was the predominant category, with nearly half of the cases requiring an intermediate level of surgical complexity.

Table 9: Distribution Based on Surgical Difficulty

Difficulty	n	%
Mild	24	30.0
Moderate	36	45.0
Severe	20	25.0
Total	80	100.0

■ Mild ■ Moderate ■ Severe

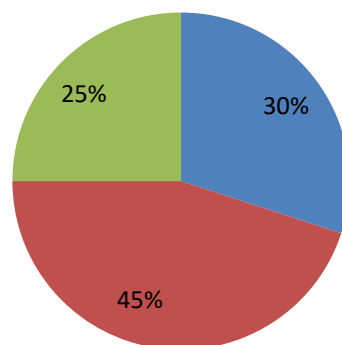


Figure 9: Distribution of Surgical Difficulty Among Impacted Maxillary Canines

Table 10 & Figure 10 present the relationship between cortical bone thickness and surgical difficulty. A statistically significant association was identified between cortical bone thickness and the level of surgical difficulty ($p < 0.001$). The mean cortical bone thickness increased progressively with increasing surgical complexity. Cases classified as having mild surgical difficulty showed the lowest mean

cortical bone thickness (1.70 ± 0.40 mm), followed by moderate difficulty (2.40 ± 0.50 mm), whereas severe difficulty demonstrated the highest mean value (3.20 ± 0.60 mm). These findings suggest that increased cortical bone thickness is associated with greater surgical difficulty during the management of impacted maxillary canines.

Table 10: Association of Cortical Bone Thickness with Surgical Difficulty

Surgical Difficulty	n	Mean (mm)	SD	SE	P value
Mild	24	1.70	0.40	0.08	<0.001
Moderate	36	2.40	0.50	0.08	
Severe	20	3.20	0.60	0.13	

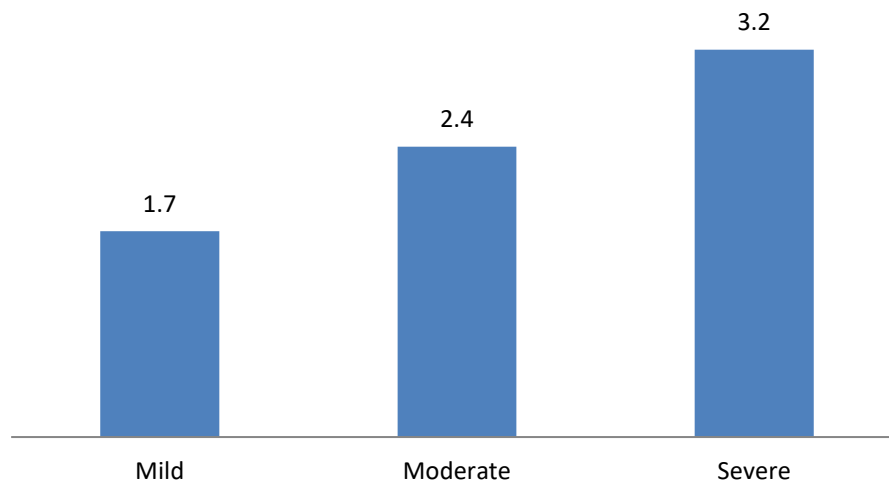


Figure 10: Association Between Cortical Bone Thickness and Surgical Difficulty

Table 11 & Figure 11 present the association between operative time and surgical difficulty. A statistically significant relationship was found between operative time and the level of surgical difficulty ($p < 0.001$). The mean operative time increased consistently with increasing surgical complexity. Cases with mild surgical difficulty had the shortest mean operative time (23.60 ± 4.80 minutes), followed by those with moderate

difficulty (38.90 ± 6.10 minutes), while severe surgical difficulty required the longest operative time (56.70 ± 8.40 minutes). These findings indicate that greater surgical difficulty was associated with a significant increase in the duration of the procedure, reflecting the additional time required to manage more complex impacted maxillary canines.

Table 11: Association of Operative Time with Surgical Difficulty

Surgical Difficulty	n	Mean	SD	SE	P value
Mild	24	23.60	4.80	0.98	<0.001
Moderate	36	38.90	6.10	1.02	
Severe	20	56.70	8.40	1.88	

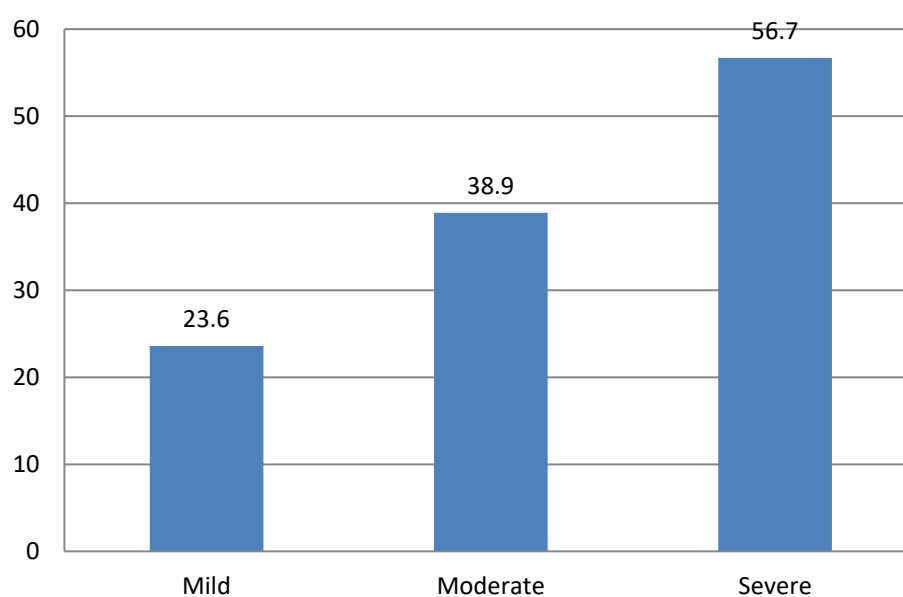


Figure 11: Association Between Operative Time and Surgical Difficulty

Table 12 & Figure 12 illustrate the relationship between the distance of the impacted maxillary canine from the occlusal plane and surgical difficulty. A statistically significant association was observed between these variables ($p < 0.001$). The mean distance from the occlusal plane increased with the level of surgical difficulty. The mild difficulty group had the lowest mean distance (8.5 ± 2.1 mm), followed

by the moderate difficulty group (11.8 ± 2.8 mm), while the severe difficulty group exhibited the highest mean distance (15.7 ± 3.2 mm). These results indicate that impacted canines positioned farther from the occlusal plane are more likely to be associated with greater surgical difficulty, highlighting the influence of impaction depth on surgical complexity.

Table 12: Association of Distance from Occlusal Plane with Surgical Difficulty

Surgical Difficulty	n	Mean (mm)	SD	SE	P value
Mild	24	8.5	2.1	0.43	<0.001
Moderate	36	11.8	2.8	0.47	
Severe	20	15.7	3.2	0.72	

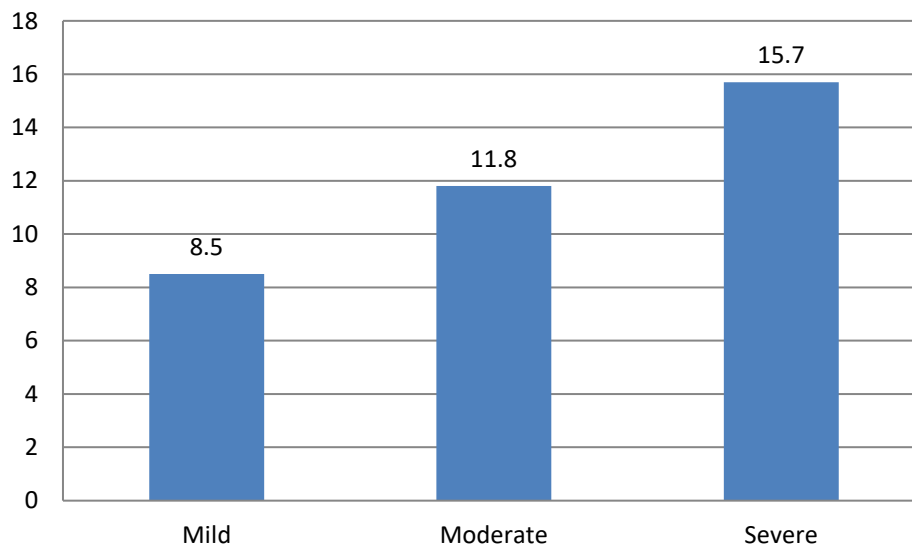


Figure 12: Association Between Distance from the Occlusal Plane and Surgical Difficulty

Table 13: Association of Follicular Space Width with Surgical Difficulty

Difficulty	n	Mean (mm)	SD	SE	P value
Mild	24	2.2	0.5	0.10	<0.001
Moderate	36	2.9	0.7	0.12	
Severe	20	3.7	0.8	0.18	

Table 13 & Figure 13 present the association between follicular space width and surgical difficulty. A statistically significant relationship was observed between follicular space width and

the degree of surgical difficulty ($p < 0.001$). The mean follicular space width increased progressively across the surgical difficulty categories. Cases with mild surgical difficulty

had the smallest mean follicular space width (2.2 ± 0.5 mm), followed by those with moderate difficulty (2.9 ± 0.7 mm), whereas the severe difficulty group demonstrated the highest mean value (3.7 ± 0.8 mm). These findings suggest

that a greater follicular space width is associated with increased surgical difficulty, indicating that follicular enlargement may contribute to the complexity of surgical management of impacted maxillary canines.

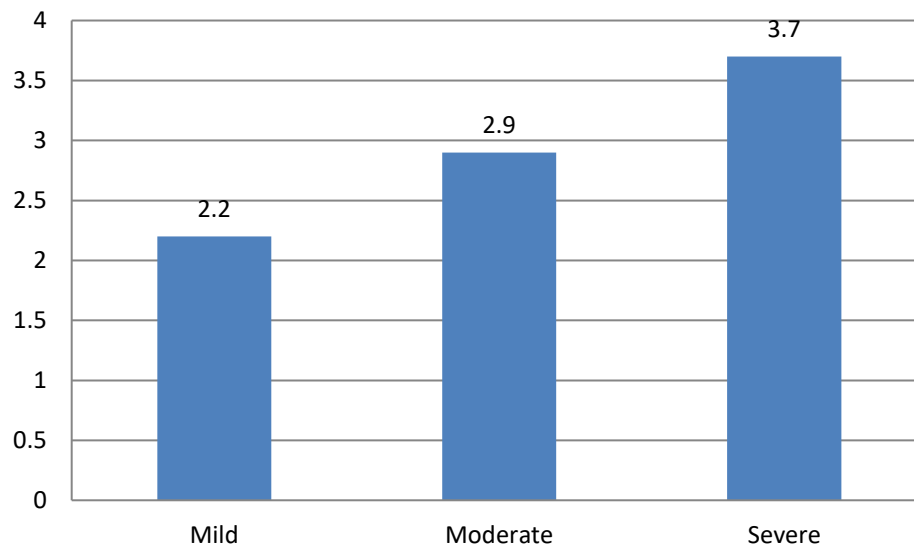


Figure 13: Association Between Follicular Space Width and Surgical Difficulty

Table 14 presents the results of the logistic regression analysis evaluating factors associated with surgical difficulty. Impaction depth was identified as a significant predictor of increased surgical difficulty (OR = 3.82, 95% CI: 1.90–7.69, $p < 0.001$), indicating that deeper impactions were more likely to require complex surgical management. Cortical bone thickness showed the strongest association with surgical

difficulty (OR = 4.16, 95% CI: 2.01–8.63, $p < 0.001$). In addition, palatal impaction (OR = 2.71, 95% CI: 1.28–5.74, $p = 0.009$) and the presence of root dilaceration (OR = 2.43, 95% CI: 1.11–5.34, $p = 0.028$) were found to be significant independent predictors. Collectively, these findings demonstrate that all four variables were significantly associated with increased surgical difficulty ($p < 0.05$).

Table 14: Logistic Regression of Surgical Difficulty with Various Independent Variable

Variable	OR	95% CI	p
Impaction depth	3.82	1.90–7.69	<0.001
Palatal position	2.71	1.28–5.74	0.009
Cortical thickness	4.16	2.01–8.63	<0.001
Root dilaceration	2.43	1.11–5.34	0.028

Interpretation: Statistical significance was considered at $p < 0.05$.

Table 15 presents the findings of the ROC analysis performed to evaluate the diagnostic performance of the studied predictors for

surgical difficulty. The combined prediction model demonstrated the highest diagnostic accuracy, with an AUC of 0.892, a sensitivity of

86.5%, and a specificity of 82.4% at an optimal cut-off value of 0.62. Among the individual variables, impaction depth showed the best predictive performance (AUC = 0.842, sensitivity = 81.0%, specificity = 77.0%) with a cut-off value of 6.5 mm, followed by cortical

bone thickness (AUC = 0.815, sensitivity = 79.2%, specificity = 75.6%) at a cut-off value of 2.8 mm. Overall, the combined prediction model demonstrated greater discriminative ability for identifying surgical difficulty than any single predictor evaluated in the study.

Table 15: Diagnostic Performance of Individual Predictors

Predictor	AUC	Sensitivity	Specificity	Cut-off
Combined model	0.892	86.5%	82.4%	0.62
Impaction depth	0.842	81.0%	77.0%	6.5 mm
Cortical thickness	0.815	79.2%	75.6%	2.8 mm

Discussion

The present study highlights the value of CBCT as a reliable imaging modality for predicting the surgical difficulty of impacted permanent canines. Accurate three-dimensional visualization of the impacted tooth and its relationship with surrounding anatomical structures enables comprehensive assessment of factors such as tooth position, depth of impaction, angulation, cortical bone coverage, root morphology, and proximity to adjacent teeth, all of which may influence operative complexity. In agreement with the present findings, Alfaiy et al. (2023) [10] demonstrated that CBCT possesses significantly greater diagnostic accuracy than conventional two-dimensional imaging techniques for the localization and assessment of impacted maxillary canines. Their findings emphasized that CBCT closely corresponds with intraoperative observations, thereby improving diagnostic confidence and facilitating more precise surgical planning.

An important observation in the present investigation was the association between the impacted canine and adjacent root structures. Teeth exhibiting close root contact were associated with increased surgical complexity because of the greater risk of damaging neighboring teeth during surgical exposure or

extraction. Algerban et al. (2011) [11] similarly reported that CBCT is significantly more accurate than panoramic radiography for localizing impacted maxillary canines and identifying root resorption of adjacent teeth. This enhanced diagnostic capability enables clinicians to recognize high-risk cases before surgery and adopt appropriate treatment strategies. Supporting these findings, Lai et al. (2013) [12] demonstrated that CBCT is highly effective in detecting external root resorption associated with impacted canines, while Ng et al. (2024) [13] further confirmed its ability to accurately evaluate both the prevalence and severity of resorption affecting adjacent incisors. Collectively, these studies reinforce the importance of CBCT in minimizing diagnostic uncertainty and preventing treatment-related complications.

The present study also demonstrated that the anatomical relationship between the impacted canine and adjacent structures substantially influences surgical difficulty. Impacted canines located close to the roots of neighboring incisors, the nasal floor, or the maxillary sinus often require more extensive bone removal and careful surgical manipulation, increasing operative time and technical complexity. Consistent with these observations, Yan et al. (2012) [14] reported that the risk of external

root resorption rises significantly when impacted maxillary canines are positioned in close physical proximity to adjacent teeth, highlighting the clinical importance of detailed three-dimensional anatomical assessment before surgery.

Overall, the findings of the present study support the routine incorporation of CBCT into the preoperative evaluation of impacted permanent canines, particularly in cases where conventional radiographs provide insufficient anatomical information. Comprehensive three-dimensional imaging allows clinicians to estimate surgical difficulty more accurately, optimize surgical access, reduce unnecessary bone removal, minimize the risk of injury to adjacent structures, and provide more accurate prognostic information during patient counseling. Kapila and Nervina (2015) [15] similarly emphasized that CBCT should be used whenever three-dimensional information is expected to influence diagnosis, treatment planning, or clinical outcomes, especially in patients with impacted teeth.

Despite the encouraging findings, several limitations should be considered. The retrospective design and single-center setting may limit the generalizability of the results, and the relatively modest sample size may not fully represent the diversity of impacted canine presentations encountered in clinical practice. Future prospective, multicenter studies involving larger populations and longer follow-up periods are recommended to validate the predictive model and establish standardized CBCT-based criteria for assessing surgical difficulty. Nevertheless, the present study provides clinically meaningful evidence that specific CBCT-derived radiographic parameters can serve as valuable predictors of surgical

complexity, thereby enhancing preoperative planning and improving the safety and predictability of impacted canine management.

Limitations

The retrospective nature of the investigation may have introduced inherent selection bias. As the study was conducted at a single center, the findings may not be fully generalizable to broader populations. Differences in surgical experience among operators could have influenced the assessment of procedural difficulty despite the use of standardized criteria. In addition, long-term postoperative outcomes were not evaluated, and the predictive model was not externally validated in an independent patient cohort. Future multicenter prospective studies with larger sample sizes are warranted to confirm these findings.

Conclusion

The present study demonstrates that CBCT is an effective imaging modality for estimating the surgical difficulty of impacted canine management through detailed three-dimensional assessment of tooth position and surrounding anatomical structures. Radiographic characteristics such as impaction depth, palatal location, cortical bone thickness, root morphology, and proximity to adjacent teeth were identified as important determinants of surgical complexity. Incorporating these parameters into routine preoperative assessment may facilitate more accurate treatment planning, improve surgical efficiency, reduce procedural complications, and enhance patient care. Further prospective multicenter investigations are recommended to validate these findings and establish standardized CBCT-based predictive models for impacted canine surgery.

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