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Comparative evaluation of root volume of maxillary lateral incisors adjacent to impacted canine: A cross-sectional CBCT study

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Abstract
Background: Maxillary canine impaction is frequently associated with morphological variations of adjacent lateral incisors. However, the role of root volume remains inadequately explored.
Aim: To evaluate and compare the root volume of maxillary lateral incisors adjacent to impacted canines and to assess its correlation with impaction severity.
Materials and Methods: A retrospective cross-sectional CBCT study was conducted on 24 patients with unilateral impacted maxillary canines. Root length and volume were measured using standardized volumetric segmentation. Impaction severity was assessed using the KPG index. Intergroup comparisons were performed using paired t-tests, and correlations were evaluated using Spearman's coefficient.
Results: Lateral incisors adjacent to impacted canines demonstrated significantly reduced root length and volume compared to the contralateral side ($p < 0.05$). A significant negative correlation was observed between KPG score and root volume.
Conclusion: Reduced lateral incisor root volume is associated with impacted canines and may influence eruption patterns. CBCT-based volumetric analysis offers a reliable diagnostic adjunct for early risk assessment.

Keywords: Impacted canine, CBCT, lateral incisor, root volume, KPG Index

Introduction

The permanent maxillary canine is the second most frequent tooth to be impacted, following the third molar. Its prevalence accounts up to 2% in the general population. About 85% of the maxillary impacted canines are located palatally; as opposed to 15% that are buccally positioned. Although, buccally positioned canines are not a rare finding. Females show a strong prevalence over males for maxillary canine impactions, with a gender predilection ratio of 2:1 [1]. Patients having impacted canines often undergo prolonged orthodontic treatment contingent on its level of difficulty and distance from the ideal occlusal plane. There are several etiological factors associated with the occurrence of impaction. Goje *et al* [1] suggest two theoretical explanations for their complex etiology. (1) Genetic theory. (2) Guidance theory. The former illustrates the role of genes in several dentofacial anomalies, among which the impaction of canines is a significant feature. The guidance theory stresses on the role of the lateral incisor, that is, its genesis, size, and shape in guiding the canine tooth into its ideal position [2]. The lateral incisor plays a critical role in guiding canine eruption, as proposed by the guidance theory. While previous studies have primarily focused on crown morphology and root resorption, limited attention has been given to root volume as a three-dimensional parameter [3]. With the advent of CBCT, it is now possible to quantify root morphology more precisely [4]. According to Becker *et al* [5], the developing maxillary canine normally erupts by following a path along the distal surface of the root of the lateral incisor, which acts as a natural guide. When the lateral incisor is absent, peg-shaped, malformed, or malpositioned, this guidance mechanism is disrupted, causing the canine to deviate from its normal eruption path, most commonly toward the palate, resulting in impaction. This theory is supported by clinical observations showing a strong association between palatally displaced canines and anomalies of lateral incisors. Chhutani *et al* [6] who demonstrated a significant association between higher KPG scores and increased severity of root resorption. However, while their study emphasized resorptive damage, the present findings suggest that KPG score may relate more strongly to volumetric characteristics than to linear root measurements but no root volume comparisons were investigated. Understanding whether reduced root volume is a predisposing factor or a consequence of impaction remains a critical gap in orthodontic research. Addressing this question has important implications for early diagnosis and interceptive treatment. Given these gaps, there is a compelling need to compare lateral root volume adjacent to impacted canine with a more advanced and standard approach. Such studies are essential to provide relevant evidence for guiding future improvement. The confidence interval was set at 95% and probability of alpha error (level of significance) was set at 5%
Ethical approval: Obtained from Institutional Ethics Committee (Ref. No. STU/IEC/2024/425).

Materials and Methods

Study Design

Retrospective observational cross-sectional study of 48 patients treated at Pacific Dental College and Hospital, Debari
24 CBCT scans of patients aged 12–28 years with unilateral impacted maxillary canine were collected from the Department of Orthodontics and Dentofacial Orthopaedics. The 48 patients were divided into two groups i.e the unilateral maxillary impacted canine and the non-impacted side.
Inclusion criteria: Unilateral impacted canine; no prior orthodontic treatment; non-syndromic. Figure 1

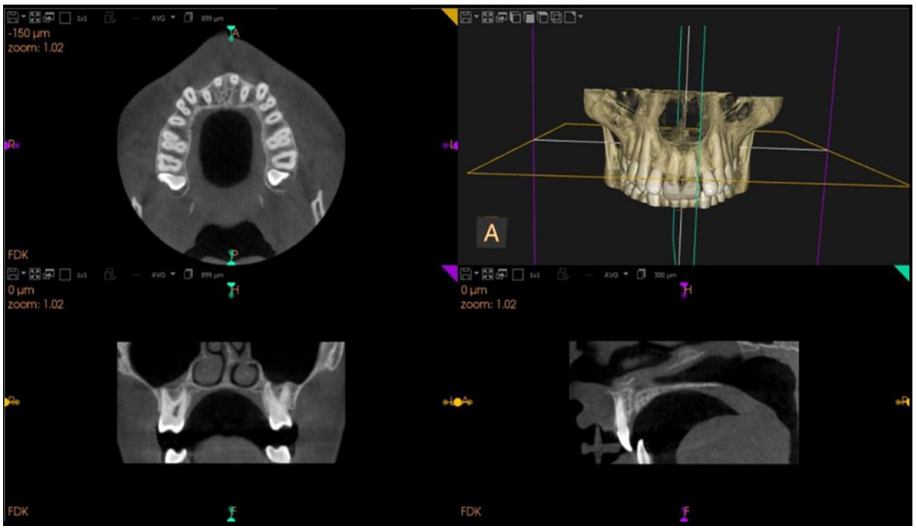

Fig 1

Exclusion criteria: Bilateral impaction; craniofacial anomalies; supernumerary teeth; cystic lesions; prior treatment of lateral incisors.

CBCT scans were obtained with standard parameters (FOV 10×5 cm; voxel size 300 µm; 80 kVp; 4 mA) and analyzed using CS 3D Imaging Software (Carestream Health™, Rochester, NY, USA). (Figure 1)

Using KPG index the maxillary impacted canine were classified based on the KPG Score. Impaction severity assessed using the KPG index (X, Y, Z axes; scores ranged from 0–5). figure 2

Level	Original KPG
Easy	0-9
Moderate	10-14
Difficult	15-19
Extreme	≥20

Fig 2

Measurements were done for the Root length from CEJ to apex in axial plane. (figure 3). The area of maxillary lateral incisor was measured in coronal section at 1mm interval thickness (figure 4) by the osteoid *in vivo* [7] tool. It was multiplied to each layer by 1mm thickness upto the root length of each tooth. The above steps for the measurement of root volume for lateral incisor were repeated for each side ie. The impacted canine side and non-impacted canine side.

Fig 3

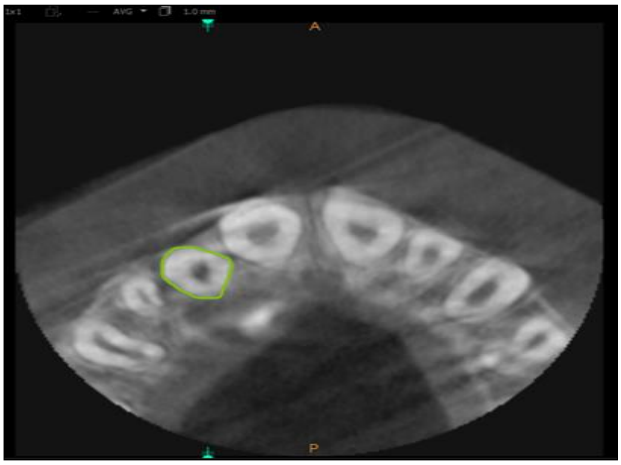

Fig 4

To control method errors all measurements were performed by a single calibrated examiner and repeated after a two-week interval to assess intra-examiner reliability. Statistical analysis were analyzed using SPSS version 21 (IBM Corp, Chicago, IL, USA). ANOVA t test was used for comparison between the groups. Spearman's Rho test was used for correlation between the KPG Index Scoring and the Root Volume and Root Length of Lateral Incisors.

Results

The study included 24 subjects (mean age 16.25 ± 3.22 years; 58.3% males). The majority of cases were categorized as easy to moderate based on KPG scores. Root length and root volume were significantly lower on the impacted side compared to the non-impacted side ($p < 0.05$). The difference in root length showed high statistical significance ($p < 0.001$). A significant negative correlation was observed between KPG score and both root length and root volume.

Table 1: Descriptive statistics of study population

Parameter	Value
Total sample	24
Male	14 (58.3%)
Female	10 (41.7%)
Mean age	16.25 ± 3.22 years
Mean KPG score	9.208 ± 5.004

Table 2: Distribution of KPG score

Category	Frequency	Percentage
Easy	14	58.3%
Moderate	9	37.5%
Difficult	1	4.2%

Table 3: Comparison of root length (mm)

Parameter	Mean ± SD	t-value	p-value
Impacted	14.00 ± 1.17	6.133	<0.001*
Non-impacted	15.83 ± 0.86		

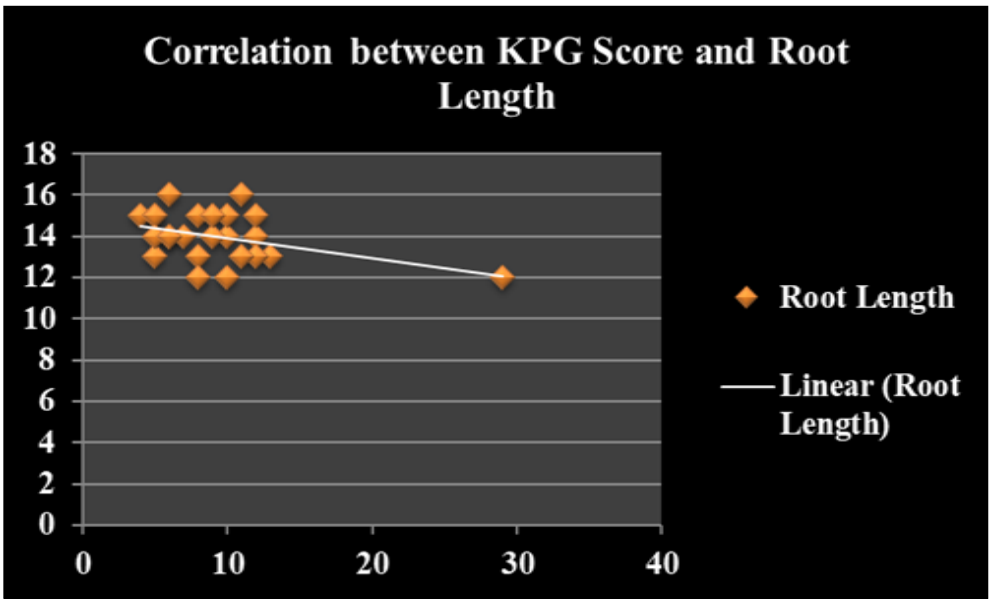

Table 4: Comparison of root volume

Parameter	Mean ± SD	t-value	p-value
Impacted	3.837	0.775	<0.05*
Non-impacted	3.857		

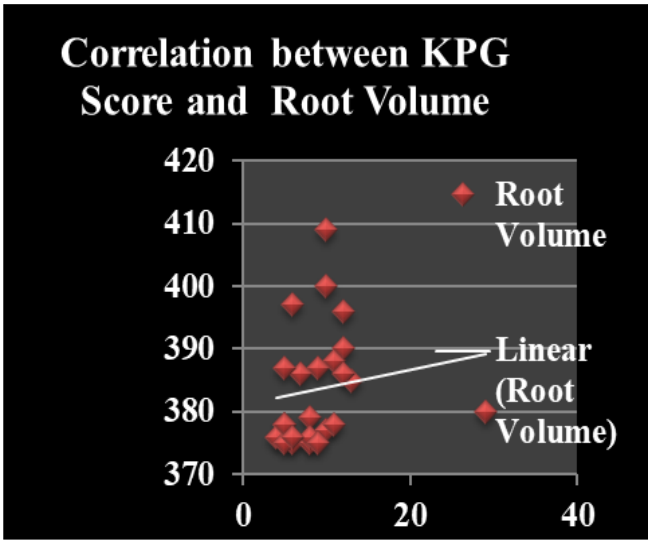

Table 5: Correlation between KPG score and root length

Variable	Correlation (r)	p-value
KPG vs Root Length	1.000 0.309	<0.05*

Table 6: Correlation between KPG score and root volume

Variable	Correlation (r)	p-value
KPG vs Root Volume	1.000 0.423	<0.05*

Discussion

In order to improve facial and aesthetic profiles, patients having impacted canines often undergo prolonged orthodontic treatment contingent on its level of difficulty and distance from the ideal occlusal plane. There are several etiological factors associated with the occurrence of impaction [2]. Impacted maxillary canines can significantly affect the root length and root volume of lateral incisors

through external root resorption. This process may lead to shortened roots, decreased root volume, reduced periodontal support, and possible tooth loss if not detected and managed early. The follicle and crown of the impacted canine come into close proximity with the lateral incisor root. Continuous pressure stimulates odontoclast activity, causing resorption of cementum and dentin. As resorption progresses toward the apex, the apical portion of the root becomes shortened [1, 4].

The present study aimed to evaluate the relationship between the KPG index and root morphology of lateral incisors, particularly focusing on root volume and root length differences between impacted and non-impacted teeth. Impacted teeth are a frequently encountered clinical condition in orthodontics and may lead to complications such as malocclusion, root resorption of adjacent teeth, periodontal problems, and esthetic concerns. Accurate evaluation of impacted teeth and the prediction of treatment difficulty are therefore essential for effective orthodontic management [7]. The occurrence of impacted maxillary canines has been widely studied, with Ericson and Kurol 10 and Becker *et al* [5]. reporting that dental impactions occur frequently. Their findings emphasize that local anatomical and developmental factors play a more critical role in the etiology of impaction. Earlier diagnostic approaches relied on two-dimensional radiographic techniques, as discussed by Ericson and Kurol *et al* [7], which were limited by distortion, superimposition, and reduced sensitivity in detecting early root resorption.

Botticelli *et al* [8] demonstrated that CBCT significantly improves the detection of root resorption and provides a more precise spatial understanding compared to two-dimensional radiography, which tends to underestimate pathology due to distortion and superimposition. Therefore, the present findings are consistent with previous evidence, reinforcing that CBCT is essential not only for localization and treatment planning but also for precise morphometric analysis of root alterations adjacent to impacted canines. Similarly, Yoojun Kim and Hong-Keun Hyun *et al* [9]. demonstrated that smaller lateral incisor root size and larger canine crown dimensions are significant etiological factors in canine impaction. The study sample was derived exclusively from a Korean population, which may limit the external validity of the results. Craniofacial morphology, dental arch dimensions, and patterns of canine impaction are known to vary across ethnic groups; therefore, the prevalence and severity of root resorption observed in the study may not accurately reflect those seen in the Indian population.

Furthermore, Yan *et al* [10]. observed that root resorption most frequently affects the apical third of the lateral incisors. These finding correlates well with the reduction in root length observed in the present study, as apical resorption would directly contribute to shortening of the root length. In addition, no reduction in root volume is identified in our study provides a more comprehensive three-dimensional representation of the resorptive process, capturing not only linear loss but also the overall structural changes of the root. This highlights the advantage of volumetric CBCT analysis in detecting subtle changes that may not be apparent through conventional measurements.

The negative correlation between KPG score and root volume indicates that more severe impactions are associated with reduced root morphology. However, the relationship may be bidirectional, as reduced root volume may predispose to impaction or result from pressure exerted by the impacted canine. CBCT allowed precise three-dimensional evaluation, overcoming limitations of conventional radiography.

Limitations

The limitations of the present study should be considered when interpreting its findings. The cross-sectional design prevents establishing a causal relationship between root volume differences and canine impaction, leaving it unclear whether these changes are a cause or consequence. The study relied solely on CBCT-derived root volume measurements and did not assess other relevant factors such as crown dimensions, tooth morphology, or eruption path.

Patients with missing or malformed lateral incisors were excluded, limiting generalizability. Although the sample size was adequate, it was relatively small and drawn from a single population, which may reduce external validity. Most cases were classified as easy or moderate based on KPG scores, suggesting relatively low to moderate complexity. This may explain the preservation of root volume and moderate correlations observed, while the limited number of difficult cases represents a sampling limitation.

Clinical Implications

Early CBCT assessment can identify at-risk patients. Reduced root volume may serve as a predictive marker for impaction severity and guide interceptive orthodontic treatment.

Conclusion

The present study was undertaken to evaluate to evaluate and compare the root volume of maxillary lateral incisors adjacent to impacted canine. While several studies have investigated the root length changes in the lateral incisor adjacent to the impacted canine, to the best of our knowledge, limited literature exists comparing the root volume.

The present study concluded that the:

- The root length of maxillary lateral incisor on impacted and non-impacted side was slightly different which was also found statistically significant.
- The root volume maxillary lateral incisor on impacted and non-impacted side was almost same.
- No significant correlation was found between KPG Score and the root length of maxillary lateral incisor on impacted side.
- Statistically significant correlation was found between KPG Score and the root volume of maxillary lateral incisor on impacted side.
- In the KPG score interpretation Among 24 subjects 14 (58.3%) subjects scored easy KPG score, 9 (37.5%) subjects scored moderate and only 1(4.2%) subject scored difficult KPG score.

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