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Original Research Article

Effect of severity of impacted maxillary canine on the root-crown ratio and volume of ipsilateral central, lateral incisors, and first premolar: A cross-sectional study

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Abstract

Aim and Objective: To evaluate the root-crown ratio and volumetric changes in teeth adjacent to impacted maxillary canine and to correlate with the severity of impaction.

Background: There are limited studies that have assessed the differences in the root-crown ratios and volumes of teeth adjacent to maxillary canines that are impacted. Also, these dimensional changes have not been correlated to the severity of impaction.

Materials and Methods: Forty pre-treatment CBCT scans of patients with unilateral maxillary canine impaction were included in this cross-sectional study. The contralateral teeth on the non-impacted side were taken as control. CS Imaging and ITK-SNAP softwares were used to assess the root-crown ratios and volumes, respectively. KPG Index was utilized to assess the severity of canine impaction. The root-crown ratio and volumetric changes of the adjacent teeth were correlated with the cumulative KPG score.

Results: The teeth adjacent to the impacted maxillary canine showed a significant decrease in the root-crown ratio and volume. Positive correlation was observed in the Easy, Moderate, and Difficult categories for the change in root-crown ratio and volumes of central incisors, lateral incisors and first premolars. Extremely Difficult category was positively correlated to central incisors, and negatively correlated to the lateral incisors and first premolars.

Conclusion: The root-crown ratios and volumes of adjacent teeth on the impaction side was lower as compared to the non-impaction side and is affected by the Easy, Moderate and Difficult categories of KPG Index.

Keywords: Resorption, Impaction, CBCT, Volume, Root-crown ratio, KPG Index, ITK Snap

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1. Introduction

A tooth is impacted if there is a failure of eruption even after normal development is complete.[1] Wisdom teeth are the most commonly impacted followed by the maxillary canines. The prevalence of impaction in maxillary canines was 0.9-3.3% in Caucasian population[2] while it was 1.38% in Indian population.[3] The cone-beam computed tomographic (CBCT) imaging enables three-dimensional evaluation of root structure and thus has higher sensitivity for the detection of root resorption and developmental anomalies.[4]

Several studies utilizing pre-treatment orthopantomographs have shown the association of impacted maxillary canine with agenesis, displaced tooth buds of adjoining teeth, and deformed lateral incisors.[3,5-7] Lateral incisor root on the impaction side was shorter in comparison to the contralateral control in a CBCT study by Al-Tawachi et al.[8] for palatally impacted canines.

Root resorption could also be a potential factor which decreases the root length and volume of teeth in proximity to the impacted canine. This pressure related resorption induced by the impacted canine is termed as canine-induced root resorption.[9] Pre-treatment CBCT scans evaluated by various studies,[10-13] have demonstrated this type of resorption in teeth adjacent to the impacted canine. Guarnieri et al.[11] demonstrated the resorption of the palatal root of teeth adjacent to a palatal maxillary canine impaction. Buccal root resorption was observed in teeth adjacent to buccally displaced canines while mid-alveolar impactions had a lesser

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incidence of resorption of proximal teeth. This was attributed to the pressure exerted by the impacted canine on the proximal tooth roots.

The studies that have evaluated the differences in the root-crown ratio and volume on the adjacent teeth due to impacted maxillary canine is limited. Also, these dimensional changes were not correlated to the severity of maxillary canine impaction. Hence, the purpose of this study was two-fold;[1] comparison of the root-crown ratio and volume of the central incisor, lateral incisor, and the first premolar teeth of the impacted side to the contralateral teeth on pre-treatment CBCT scans and, to correlate the changes in root-crown ratio and volumes with the severity of impacted maxillary canine as assessed by KPG Index.

2. Materials and Methods

This cross-sectional study was conducted after the approval by the Institute Ethical Committee (NK/7971/MDS/720). Helsinki protocol was followed. CBCT scans of patients who were enrolled for comprehensive orthodontic therapy for the management of impacted maxillary canines were evaluated. All the CBCT scans were taken in natural head position using Kodak 9500C (Carestream Health Inc. Onex Corporation). Standardization of exposure was followed for all the CBCT scans at 90 KV, 10 mA, 14.20 seconds, and voxel size of 200 µm × 200 µm × 200 µm with a slice thickness of 0.2 mm. Screening of sixty pre-treatment CBCT scans was done.

Patients with unilateral maxillary canine impaction with the presence of central incisor, lateral incisor, and first premolar with healthy periodontium on both sides of the maxillary arch were included. Informed consent was obtained. The exclusions criterion were bilaterally impacted canines, patients less than 10 years of age, agenesis, or extraction of teeth adjacent to maxillary canines, congenital anomalies and syndromes, generalized microdontia, root dilacerations, history of dental trauma, and CBCT scans of poor quality. The maxillary arch was divided into impaction side and non-impaction side. Impaction side is the quadrant of the maxillary arch where the impacted canine was located. The non-impaction side served as control.

The final sample comprised of forty patients whose CBCT scans were assessed for root-crown ratio and volume of the central incisor, lateral incisor, and first premolar on the impaction side and compared to the corresponding teeth on the non-impaction side. Quorum flowchart depicted by **Figure 1** gives an overview of the sample selection process. KPG index[14,15] was used to categorize the severity of canine impaction into Easy, Moderate, Difficult, and Extremely Difficult based on the cumulative scores of cusp and root tip in three planes of space.

2.1. Root-crown ratio

The root-crown ratio was evaluated utilizing CS Imaging Software (Version 3.2.9). Lind technique[16] was utilized in the evaluation of the root-crown ratio. A description of the landmarks used for calculating the root-crown ratio is shown in **Figure 2**.

2.2. Volume estimation

The tooth of interest was segmented utilizing ITK-SNAP software (Version 3.8.0) to assess the volumetric changes as depicted in **Figure 3**. The polygon tool was used to delineate the tooth of interest in each slice of transverse, sagittal, and coronal planes. After defining all the sections of the tooth, the final image was updated. The volume of the segmented tooth was calculated using the Volume and Statistics segmentation tool.

The investigator (PK) was calibrated for landmark identification, measurement of root length, crown length, and volume estimation on CBCT scans. The intra-examiner reliability was assessed by repeating the measurements on 10% of all the CBCT scans selected randomly after an interval of 3 weeks.

3. Statistical Analysis

Statistical Package for Social Sciences software (SPSS Inc., Chicago, IL, version 22.0 for Windows) was used for statistical analysis. Descriptive statistics were performed by calculating the mean and standard deviation of continuous variables. Unpaired t-test was used to compare the root-crown ratio and the volumetric changes between the impaction and the non-impaction side. Shapiro-Wilk test was used to assess quantitative data normality. Pearson's correlation was used to assess the strength of association between canine impaction severity and the root-crown ratio and volume change of teeth adjacent to the impacted maxillary canine. The level of significance was kept at 95% confidence interval and p-value less than 0.05.

4. Results

Intra-class correlation coefficient of root-crown ratio and volume estimation was 0.968-0.993 and 0.965-0.994 respectively, which showed excellent intra-examiner reliability. **Table 1** depicts the demographic details. The mean age of male and female patients was 18.83±5.80 (age range of 13-36 years) and 19.59±8.27 years (age range of 11-45 years), respectively. There was a statistically significant decrease in the root-crown ratio and volume of central, lateral incisor, and first premolar on the impaction side in comparison to the non-impaction side (**Table 2**).

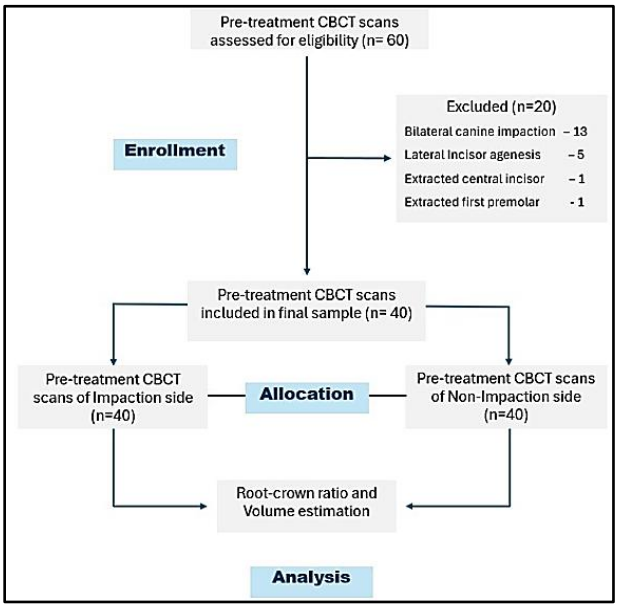

Figure 1: Flow chart of sample selection and study design

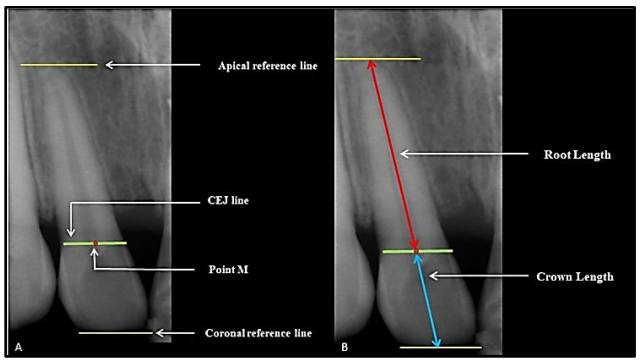

Figure 2: Description of root-crown ratio assessment; 2A: Apical reference line (Line through the apex of the teeth parallel to the coronal reference line); Cemento-enamel junction (CEJ) line (line connecting the junction of the outer contours of root and crown on the transverse plane); Point M (Midpoint of CEJ line); and Coronal Reference line (Line tangent to the incisal edge); 2B: Measurement of Root Length (distance from Point M to apical reference line along the long axis of the tooth) and Crown Length (distance from Point M to coronal reference line along the long axis of the tooth)

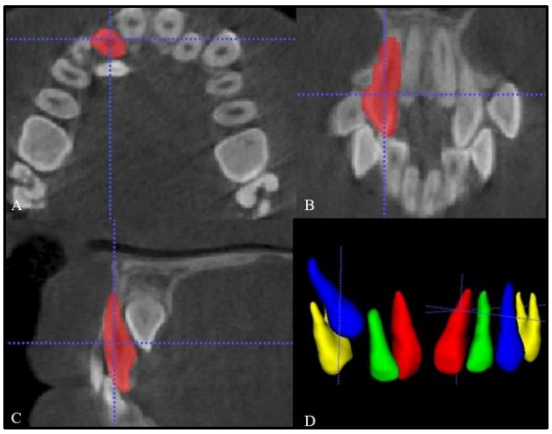

Figure 3: Polygon Tool used to delineate the tooth of interest in each slice of Transverse (3A), Coronal (3B), and Sagittal (3C) planes for volume estimation; (3D) Completed segmentation.

The Easy, Moderate, and Difficult categories showed a significant positive correlation to the change in the volume of maxillary central and lateral incisors and first premolars (**Table 3**). The Extremely Difficult category showed a significant negative correlation to the mean change in root-crown ratio and volumes of maxillary lateral incisor and first premolar. However, the Extremely Difficult category showed a significant positive correlation to the mean change in the root-crown ratio and volume of maxillary central incisor (**Table 3**).

Table 1: Demographic details

S.no	Parameters		Number	Percent (%)
1.	Gender	Male	18	45
		Female	22	55
2.	Location	Buccal	7	17.5
		Palatal	24	60
		Mid-alveolar	9	22.5
3.	Laterality	Right	19	47.5
		Left	21	52.5
4.	KPG Index	Easy (0-9)	4	10
		Moderate (10-14)	26	65
		Difficult (15-19)	8	20
		Extremely difficult (20-30)	2	5

Table 2: Comparison of root-crown ratio and volume of central, lateral incisor and first premolar on impaction side and non-impaction side

Parameter	Tooth	Mean ± SD		MD	CI (95%)		T-Value	P-Value
		Impaction side	Non-impaction side		Lower limit	Upper limit		
Root-crown ratio	Central Incisor	1.30±0.20	1.41±0.18	-0.11	-0.16	-0.06	-4.653	0.001
	Lateral Incisor	1.39±0.26	1.59±0.20	-0.20	-0.27	-0.13	-6.096	0.001
	First Premolar	1.51±0.24	1.69±0.20	-0.18	-0.25	-0.11	-5.135	0.001
Volume (mm^3)	Central Incisor	591.81±94.12	614.96±98.75	-23.15	-33.82	-12.48	-4.390	0.001
	Lateral Incisor	357.36±68.68	406.83±68.79	-49.46	-60.18	-38.74	-9.330	0.001
	First Premolar	552.73±91.21	584.77±89.73	-32.03	-44.21	-19.85	-5.320	0.001

MD- Mean difference; CI-Confidence Interval
p>0.05- Non-significant; p<0.05- Significant; p< 0.01- Highly significant; p<0.001- Very highly significant

Table 3: Correlation between various categories of KPG Index and mean difference in root-crown ratio and volume of teeth between impaction side and non-impaction side

Category of KPG Index	Root-Crown Ratio (Mean Difference)						Volume (Mean Difference)					
	Central Incisor		Lateral Incisor		First Premolar		Central Incisor		Lateral Incisor		First Premolar	
	r	P-value	r	P-value	r	P-value	r	P-value	r	P-value	r	P-value
Easy (n=4)	0.998	0.002	0.805	0.019	0.549	0.451	0.998	0.002	0.983	0.017	0.969	0.031
Moderate (n=26)	0.731	0.001	0.614	0.001	0.556	0.003	0.919	0.001	0.859	0.001	0.874	0.001
Difficult (n=8)	0.182	0.666	0.611	0.018	0.562	0.047	0.983	0.001	0.923	0.001	0.992	0.001
Extremely difficult (n=2)	1.000	0.001	-1.000	0.001	-1.000	0.001	1.000	0.001	-1.000	0.001	-1.000	0.001

p>0.05- Non-significant; p<0.05- Significant,; p< 0.01- Highly significant; p<0.001- Very highly significant

5. Discussion

In the present study, the root-crown ratio and volume of teeth adjoining the impacted tooth were lower compared to the contralateral teeth. The maxillary canine develops near the floor of the orbit and transverses a long tortuous course to reach its functional position in the oral cavity.[17,18] As the maxillary canine descends into the alveolus, it can cause anomalous root formation of the adjoining teeth.[5] Previous studies have shown association between impacted maxillary canines and anomalies such as agenesis, displaced tooth buds of adjoining teeth, and microdontia of lateral incisors.[3,5-7] External apical root resorption of teeth adjacent to the impacted canine has also been noted. This pressure-related root resorption termed as canine-induced root resorption is a rapidly progressive process that mostly halts once the impacted canine is moved away from the affected area.[9] The pressure exerted by the enlarging follicle and the impacted tooth could be a causative factor which mediates the root resorption of its adjacent teeth.[19] According to Ericson and Kurol,[20], 80.5% of lateral incisors adjacent to the impacted maxillary canine had undergone root resorption. Therefore, diagnosis and localization of this type of root resorption is crucial. Root-crown ratio and volume estimation are the tools that were utilized to quantitatively assess the dimensional change in the teeth adjacent to impacted maxillary canines in the present study. The root-crown ratio measures the root length relative to the crown length and hence magnification errors are avoided.[21]

There was a marked decrease in the root-crown ratio and volumes of central, lateral incisor and first premolar on the impaction side in comparison to the non-impaction side in this study. Similarly, in a study by Razeghinejad et al.[22] there was a reduction in the volume of the lateral incisor on the impaction side. Root-crown ratio values are unaffected by different angulations and magnifications of different x-ray machines, hence providing a distinct advantage over conventional methods of measuring root resorption. Volume estimation of the CBCT image by segmentation provides an accurate quantitative depiction of the anatomy of the tooth. Resorption along the lateral surfaces of the root does not affect the root-crown ratio since the total root length remains intact. However, it can be detected through segmental volumetric analysis as there will be a decrease in the overall tooth volume. Hence, volumetric analysis is a more reliable indicator of resorption along the lateral sides of the root.

The correlation of the severity of the canine impaction to the change in root-crown ratio and volume can be attributed to its proximity to the roots of the maxillary central, lateral incisor, and first premolar. Studies by Yu et al.[23] Sajnani and King[24] revealed a positive correlation between the severity of root resorption of adjacent teeth and the distance of the maxillary canine cusp tip to the occlusal line. More severe resorption was associated with the greater overlap of lateral incisor root by the crown of impacted canine. In this study, the crown tip of the impacted maxillary canine in the Extremely Difficult category were farther away from the roots of the lateral incisor and first premolar and hence there was no decrease in the root-crown ratio and volume. However, there was a decrease in the root-crown ratio and volume of central incisor due to its proximity to the impacted canine.

Similarly, another study stated that the risk of root resorption was increased whenever the impacted maxillary canine was vertically positioned above the roots of the lateral incisor and in proximity to the median palatal suture.[25] Hence, the proximity of the impacted canine to the adjacent teeth, higher vertical positioning, and mechanical obstruction by the apex of roots of incisors, increased the risk of root resorption. Orthodontic treatment outcome is dependent on the viability of the roots of these teeth and should be given the utmost importance during diagnosis and treatment planning. The potential risk of root resorption should be weighed against the benefit of de-impaction for certain categories of impacted maxillary canines. A cross-sectional patient sample was used in this study which is a potential limiting factor. Further randomized controlled trials are necessary with a larger sample size.

6. Conclusions

A decrease in the root-crown ratio and volume of the central and lateral incisors and first premolar was evident on the impaction side and shows a positive association with the Easy, Moderate, and Difficult category of KPG-Index. Hence, orthodontists should be cautious when applying forces on teeth adjacent to impacted maxillary canine.

7. Supplementary Materials

None.

8. Authors Contribution

PK: data synthesis, software application, writing the original draft; SV: conceptualization, methodology and validation, writing – review & editing; VK: visualization of the data, review and editing; RV: analysis, validation, review and editing; SP: conceptualization, methodology and project administration, proof reading.

9. Disclosure Statement

There was no conflict of interest among the authors.

10. Data Availability Statement

The study data is available at the Unit of Orthodontics, Oral Health Sciences Centre, Postgraduate Institute of Medical Education and Research, Chandigarh.

11. Ethical Approval

Approved by the Institute Ethical Committee (NK/7971/MDS/720).

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