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Original Article

Reliability of Cone-Beam Computed Tomography in Diagnosis of Root Resorption Due to Impacted Maxillary Canine

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Abstract

Background: This study aimed to evaluate the cone-beam computed tomography (CBCT) technique considering its reliability to diagnose resorption due to maxillary impacted canine.

Methods: In this cross-sectional study, 68 CBCT images were observed by two oral and maxillofacial radiologists. The position of the impacted maxillary canine was assessed, and the severity of root resorption in adjacent teeth was determined in two rounds by viewing. Finally, statistical analyses were performed according to the percentage of agreement, intra-class correlation coefficient, and kappa. The data sheets were filled out by two radiologists who observed the CBCT images in two separate weeks and recorded their opinions about the position of the crown and root of the impacted maxillary canine. Further, four adjacent teeth were examined for root resorption.

Results: In most cases, no root resorption was observed in the lateral, central, and first premolars; however, the reported percentage of root resorption in the lateral premolar was higher than that of the others, and no root resorption was reported in the second premolars. Agreement on crown and root position was reported to be above 90% in all observations. In addition, the percentage of agreement was 98.5%, 95.6%, 98.5%, and 100% for root resorption, central incisor, lateral incisor, the first premolar, and the second premolar, respectively. Maxillary impacted canines were examined considering root resorption in adjacent teeth using CBCT, and its interpretation was reliable.

Conclusions: Utilization of CBCT provides a worthy data about the impacted maxillary canine localization and effects on adjacent teeth, for more explanation and treatment of these cases.

Keywords: Impacted maxillary canine, CBCT, Root resorption

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Introduction

Tooth impaction is a pathological condition that refers to the non-eruption of teeth in the oral cavity during the expected period of its eruption according to radiographic and clinical findings (1). Maxillary canine, which is important in terms of aesthetics and function, has the highest incidence of impaction after the third molar, and its prevalence has been reported to be 1%-3% (2). The causes of permanent maxillary canine impaction include the obstruction of the eruption pathway by bone, soft tissue lesions, adjacent teeth anomalies, and environmental and genetic factors (3). Trauma can also have consequences in changing the direction of canine tooth growth, including the displacement of the tooth bud and shortening of the root of the lateral incisor, which requires more attention to the damaged tooth in terms of the development and growth process (4). Untreated impacted canines can be associated with the malposition of adjacent teeth, shortening of the dental arch, increased chance of follicular cyst formation, and recurrent infection. External root resorption in adjacent teeth can also be an irreversible consequence and lead to tooth loss (5). It is a multifactorial biological process that involves the physiological or pathological decomposition of the mineral tissue (i.e., dentin, cementum, and adjacent alveolar bone) by clastic cells (6). This process can occur due to various reasons such as inflammation around the roots, traumatic occlusion, impacted teeth, trauma, replantation, internal tooth whitening, cysts and tumors, bacterial invasion, systemic problems, or for no apparent reason (7). Our study considered the maxillary impacted canine, rather than the follicle around the tooth, as the reason for root resorption and investigated the frequency and percentage of external root resorption in a root close to this tooth.

According to previous evidence, there is a clear relationship between the impacted canine's vertical direction in the bone and the resorption in adjacent teeth. Moreover, physical proximity (a distance of less than 1 mm) between the maxillary impacted tooth and the adjacent tooth's root is considered a predictive factor for root resorption. However, no relationship exists between age and gender with the number of teeth that suffer root resorption, the location, and the severity of root resorption (8). The radiographic examination of the impacted canine is necessary, and three-dimensional (3D) imaging is recommended, especially when the impacted canine tooth is likely to be ankylosed or cause root resorption in adjacent teeth (9). The imaging technique and subsequent radiation received by the patient must be in line with the as low as a reasonably achievable rule, and cone-beam computed tomography (CBCT) should not be the first paraclinical examination used to diagnose root resorption. The ability to correctly identify the location and size of root resorption is essential for treatment planning and defining the prognosis (6). Differences between imaging protocols, image reconstruction tools, and exposure parameters (including voltage and exposure time) can affect the ability to detect root resorption (9). In the past, periapical (PA) images were a common tool for detecting root resorption, but recent studies indicate that these images have severe limitations and may underestimate root resorption. Furthermore, they lead to false negative and positive results in 51.9% and 15.3% of cases, respectively. Root resorption can be detected on PA radiography when 60%-70% demineralization has occurred in the mineral bed structure. The main problem in the diagnosis of root resorption using PA radiographs occurs when the lesion is on the buccal or lingual surface of the root (6). Panoramic is a common 2D imaging technique that is used to examine impacted canines and provides information about the general situation, initial diagnosis, position of impacted canines, prediction of tooth growth, treatment plan, and treatment outcomes. However, this information is limited by distortion, artifacts, blurring, and structural superimposition (10). Accordingly, panoramic is not applied as a reliable imaging technique for detecting root resorption, especially if buccal or palatal dimensions are considered or if root resorption is incipient and mild. Considering that panoramic is the standard diagnostic tool in orthodontics, the risk of misinterpretation will increase in the orthodontic patient (10). Compared to panoramic and PA images, CBCT images have greater accuracy in detecting root resorption by eliminating structural and dental superimposition, clarifying the positioning of impacted teeth, and identifying related pathology (6) so that the root analysis is improved by 63% (11). However, it should be noted that CBCT is more expensive (6). The high diagnostic and therapeutic capability of CBCT has made it the technique of choice for diagnosis and treatment plans for root resorption, and orthodontists and surgeons can use its accurate information for critical diagnosis and interdisciplinary treatment plans resulting in improved surgery and orthodontic treatment (1). The present study sought to evaluate the reliability of the interpretation of CBCT regarding root resorption due to maxillary canine impaction.

Materials and Methods

Radiographic Examination and Assessment of Images

In this retrospective cross-sectional investigation, samples consisted of 68 CBCT images which were approved by the appropriate ethical committees related to the institution. Images were prepared using the Planmeca ProMax CBCT machine (with FOV = 8 × 4 in with 80 kVp, 10 mA, and an exposure time of 16 seconds). Romexis software (Version 2.9.2) was used to observe the images. The samples were gathered from a private oral and maxillofacial radiology center which had the CBCT scan data set images of subjects who had been referred for the radiographic examination of their impacted maxillary canines. The presence of a maxillary impacted canine (not around the dental follicle) in close contact with the adjacent teeth was the inclusion criterion. On the other hand, the exclusion criteria were the unacceptable quality of CBCT images, metal artifacts, and patient movement. The electronic files of the images were observed by two oral and maxillofacial radiologists who were faculty members of the school of dentistry with at least 10 years of experience. The observers were allowed to evaluate the region of interest using multiplanar and 3D images by means of all of the capabilities of Romexis software.

All CBCT images were evaluated for the buccal or palatal location of the crown and root of impacted maxillary canine, possible root resorption and its intensity in the adjacent central and lateral incisor, as well as possible root resorption and its intensity in the adjacent first and second premolars. To evaluate the reliability, observers examined the images twice in two separate weeks considering the crown and root position and the intensity of root resorption in four adjacent teeth.

The intensity of root resorption was recorded as follows:

1. If root resorption was limited to the tooth surface, it was considered "mild";
2. If root resorption was extended to dentin, it was considered "moderate";
3. If root resorption involved a root canal (pulp), it was considered "severe".

Statistical Analysis

IBM SPSS Statistics for Windows software (Version 24.0) was used to summarize and report the data in the present study. The studied variables were qualitative and reported in number and percentage.

Statistical indices consisted of kappa, intra-class correlation coefficient (ICC), and the percentage of agreement. The reliability of the diagnosis of root resorption in the adjacent tooth of the impacted maxillary canine in CBCT was analyzed as the main objective of our study.

Results

The samples of this study included 68 CBCT images of people with an impacted maxillary canine who were referred to a private oral and maxillofacial radiology center. Table 1 presents the frequency of the crown and the root position of the impacted maxillary canine based on CBCT images reported in two separate observations for each observer. The inter-observer and intra-observer reliability of the CBCT technique were evaluated regarding the localization of the root, the crown of the maxillary impacted canine (Table 2), and the diagnosis of the root resorption of adjacent teeth (Table 3) using ICC, kappa, and agreement percentage. Table 4 provides data on the distribution of root resorption severity based on CBCT images, including no resorption, with mild, moderate, and severe resorption on maxillary incisors and the first and second premolars.

Discussion

The impacted maxillary canine with a prevalence of 1-3% is critical due to its role in esthetic and function, and since it is the most prevalent after the third molar (2). The untreated impacted canine can lead to the displacement of adjacent teeth, shortening of the dental arch, increased risk of follicular cyst formation, recurrent infection, and root resorption. The root resorption of adjacent teeth

Table 1. Frequency of Crown and Root Position of Maxillary Impacted Canine in the First and Second Observation of CBCT Images by the First and Second Radiologists

	First Observer				Second Observer			
	Root Position		Crown Position		Root Position		Crown Position	
	First Time	Second Time	First Time	Second Time	First Time	Second Time	First Time	Second Time
Palatal position	48 (70.6%)	50 (73.5%)	54 (79%)	54 (79.4%)	27 (39.7%)	28 (41.2%)	52 (76.5%)	51 (75%)
Intermediate position	0 (0%)	0 (0%)	2 (2.9%)	3 (4.4%)	1 (1.5%)	1 (1.5%)	1 (1.5%)	1 (1.5%)
Buccal position	20 (29.4%)	18 (26.5%)	12 (17.6%)	11 (16.2%)	40 (58.5%)	39 (57.4%)	15 (22.1%)	16 (23.5%)

Note. CBCT: Cone-beam computed tomography.

Table 2. Kappa, ICC, and Agreement Index for Crown and Root Position of Maxillary Impacted Canine on CBCT Images by Two Radiologists in Two Observations

	1st Observer, 1st and 2nd Time		2nd observer, 1st and 2nd Time		1st & 2nd observer, 1st Time		1st & 2nd observer and 2nd Time	
	CP	RP	CP	RP	CP	RP	CP	RP
ICC	0.99	0.86	0.96	0.97	0.92	0.42	0.87	0.34
Kappa	0.96	0.97	0.96	0.97	0.83	0.41	0.76	0.33
Percent agreement	98.5%	94.1%	98.5%	98.5%	94.1%	100%	91.2%	98.5%

Note. CBCT: Cone-beam computed tomography; ICC: Intra-class correlation coefficient; CP: Crown position; RP: Root position.

Table 3. Kappa, ICC, and Agreement Index for Each Adjacent Tooth of the Maxillary Impacted Canine

	Obs1 1st and 2nd Time			Obs2 1st and 2nd Time			1st Time of Obs1 and Obs2			2nd Time of Obs1 and Obs2		
	Kappa	Agreement Index (%)	ICC	Kappa	Agreement Index (%)	ICC	Kappa	Agreement Index (%)	ICC	Kappa	Agreement Index (%)	ICC
RR1	0.33	95.6	0.34	0.18	98.5	0.49	0.85	97.1	0.85	0.65	94.1	0.66
RR2	0.13	75	0.43	0.54	95.6	0.75	0.92	63.2	0.96	0.35	60	0.5
RR4	0.28	89.7	0.43	0.17	98.5	0.12	0.59	88.2	0.87	-0.04	95.6	-0.05
RR5	0.31	100	0.19	*	100	*	*	100	*	*	100	*

Note. CBCT: Cone-beam computed tomography; ICC: Intra-class correlation coefficient; RR1: Root Resorption of central incisor; RR2: Root resorption of the lateral incisor; RR4: Root resorption of the first premolar; RR5: Root resorption of the second premolar; Obs1: First observer; Obs2: Second observer.

Table 4. Detection of the Intensity of Root Resorption (Number and Percentage) of Each of the Adjacent Teeth of Maxillary Impacted Canine in CBCT Images by Two Radiologists in both Times of Observation

	Central Incisor				Lateral Incisor				First Premolar				Second Premolar			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
1st Obs, 1st time	66 97.1%	2 2.9%	0 0%	0 0%	38 55.9%	24 35.3%	3 4.4%	3 4.4%	63 92.6%	4 5.9%	1 1.5%	0 0%	68 100%	0 0%	0 0%	0 0%
1st Obs, 2nd time	65 95.6%	2 2.9%	1 1.5%	0 0%	43 63.2%	20 29.4%	2 1.5%	3 4.4%	64 94.1%	4 5.9%	0 0%	0 0%	68 100%	0 0%	0 0%	0 0%
2nd Obs, 1st time	64 94.1%	4 5.9%	0 0%	0 0%	37 63.2%	25 36.8%	5 7.4%	1 1.5%	65 95.6%	2 2.9%	0 0%	1 1.5%	68 100%	0 0%	0 0%	0 0%
2nd Obs, 2nd time	65 95.6%	3 4.4%	0 0%	0 0%	35 51.5%	27 39.7%	4 5.9%	2 2.9%	66 97.1%	1 1.5%	1 1.5%	0 0%	68 100%	0 0%	0 0%	0 0%

Note. CBCT: Cone-beam computed tomography; Obs: Observer; 0: No resorption; 1: Mild resorption; 2: Moderate resorption; 3: Severe resorption.

can also be an irreversible consequence and cause tooth loss (5,8,12). In their research, Yan et al reported 170 patients with less than 1 mm physical proximity between the boundaries of the canine crown, and the adjacent roots were considered to be a predictive factor for root resorption (12). In our study, we considered the tight contact of the maxillary canine and adjacent tooth as the inclusion criterion. Similarly, in another study by Rahman and Fatah, this criterion was identified as a parameter with a significant effect on the incidence of root resorption (13). Given that the diagnosis of root resorption depends on the imaging method, numerous studies have compared the ability of different techniques to evaluate root resorption.

The superiority of 3D images over 2D ones is common in all studies. Using 3D visualization, the diagnostic accuracy represented an increase. These methods can provide X-ray projection orthogonally, and information from all three planes of the skull would be available (12). Due to the aforementioned results, CBCT was employed in the present research. It has been the preferred imaging technique for the diagnosis of root resorption and 3D examinations for more than a decade (14). According to the results of Ericson and Kurol, the prevalence of PA root resorption was 12% and 85% in the maxillary central and lateral incisors, respectively. In our survey, the percentage of root resorption in incisors was found to be lower (15). This difference may be due to different inclusion criteria of studies.

The present study considered the close interference of the maxillary canine with the nearby tooth, whereas the impacted canine with the clinical buccal bulge was considered the inclusion criterion in the study performed by Ericson and Kurol (15). PA radiographs, on the other hand, can also raise the probability of a false-positive in diagnosis. Haney et al (16) evaluated the case separately with both 2D radiographs and CBCT and reported 36% and 16% inconsistency in root resorption and labiopalatally position of the tooth in the maxilla, respectively. This research was accomplished in 2010 when CBCT was not as widespread as it is today, but nowadays in several studies, CBCT has been approved as a reliable technique for detecting root resorption. Further, the current study only used CBCT images but did not compare CBCT and 2D images.

In our research, the kappa index was applied to assess the reliability of the labiopalatal location, which has three buccal, palatal, and intermediate divisions. This index was also utilized in the study by Al-Homsi (12). In conclusion, after the evaluations of 2D images, the intraobserver agreement was extremely high (K = 0.83) and greater for CBCT (K = 0.87). The inter-observer agreement based on CBCT assessments was better (K = 0.68) compared with 2D imaging (K = 0.38) (17).

In the present research, which separately examined the reliability of the crown and root position only using CBCT, the agreement on the crown position was found to be above 90% in all observers and above 80% for the root position, except for one observer. Only CBCT images were employed in our analysis, while Tsolakis et al considered CBCT images as a gold standard to determine the position of impacted canine and root resorption and evaluated 2D radiographic modalities for comparison. Sensitivity, specificity, and positive predictive values were assessed among conventional 2D images. The sensitivity of the PA radiograph was higher than others; Occlusal and PA images had the highest positive predictive value, and the highest specificity was observed in panoramic (18).

Alqerban et al concluded that the confidence level for CBCT investigations was higher than for panoramic images. They also found that localization of the canine crown, interference with adjacent teeth, and evaluation of the root of the lateral incisor between 2D and 3D images were significantly different (19).

Safi et al compared 6×6 and 12×8 cm field of views (FOVs) for detecting root resorption and showed that the specificity for 6×6 and 12×8 cm FOVs was 93% and 83.90%. The sensitivity was also 93.95% and 94.4% for 6×6 and 12×8 cm FOVs, respectively. In the present study, an 8×8 cm FOV was selected for CBCT images which demonstrated that the sensitivity and specificity of the latter FOV would be acceptable for the diagnosis of root resorption (20).

According to previous reports, the amount of information obtained from 3D imaging is obviously greater than from conventional imaging (e.g., PA and panoramic imaging). Additionally, Haney et al, Botticelli et al, and Bjerklin & Ericson found that limited information can severely affect the treatment plan (16,21,22). Regarding the treatment plans resulting from 3D and 3D radiographic techniques, Haney et al indicated that 27% of the treatment plans, including teeth that were decided to remain in the jaw, exposed, or extracted using 2D images, were altered by means of 3D techniques (16). Furthermore, the results of Bjerklin and Ericson represented more root resorption in 44% of cases when they were reevaluated using CT with root resorption on incisors adjacent to maintain canines and thus led to a modification in the treatment plan (21). Considering the findings of the above-mentioned studies and our findings, CBCT had enough reliability, could enhance the accuracy of diagnosis, and led to a better treatment plan.

Conclusions

In this study, maxillary impacted canines were examined considering root resorption in adjacent teeth using CBCT, and it was concluded that the interpretation of these images would be reliable.

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Author Contributions

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Conflict of Interest Disclosures

The authors declare that they have no conflict of interests.

Ethical Statement

This study was approved by the Ethics Committee of Tehran University of Medical Sciences (Code IR.TUMS.DENTISTRY.REC.1397.081).

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