CBCT Evaluation of Impacted Canines and Root Resorption

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INTRODUCTION

Axillary canines are the second most frequently impacted teeth after the third molars, with a prevalence from 1% to 3%. In contrast to the third molar, the maxillary canine is located in a functionally and aesthetically demanding area. Most impactions of these teeth are palatal (85%), while 15% are labial. Impacted canines are more commonly seen in females than in males, and there is wide variation among different racial populations. Impacted canines can lead to varying degrees of resorption of the adjacent teeth, particularly of the lateral incisor, up to 48%. Root resorption can be difficult to diagnose with traditional two-dimensional (2-D) radiography, particularly if the canine is in direct palatal or facial position to the lateral incisor roots.

The etiology of impacted canines is unclear. It is multifactorial, and genetic and local factors may also play a role. It has been suggested that adjacent peg-shaped or missing lateral incisors result in palatal impaction due to a lack of proper guidance to the canine during eruption. Peck et al. suggested that palatal canine impaction is genetic in origin, and facial impaction is due to inadequate arch length or crowding.

Orthodontic management of the impacted canine requires accurate localization in order to surgically expose and retrieve the tooth most efficiently. Until recently, conventional 2-D radiographic imaging was commonly used for localization of impacted canines, in treatment planning and in evaluation of post-treatment results. Traditional radiographic imaging is limited because it is 2-D; the superimposition of structures reduces the clinician’s ability to visualize individual structures. Plain radiographs have several confounding factors, such as image enlargement and distortion, structure overlap, limited identifiable landmarks, and
positioning problems; these can adversely affect image quality, increasing the risk of misinterpretation. Computerized medical tomography (CT) was an improvement over previously used techniques in that it eliminates overlapping structures and allows for visualization of specific tissue volume. However, the higher radiation exposure with CT scans limits their clinical utility. The advent of three-dimensional (3-D) cone beam computerized tomography (CBCT) has resulted in lower radiation doses than those of CT, making it an advantageous imaging tool in dentistry.

A common application of CBCT is in the evaluation and surgical treatment planning of impacted teeth. An example of impacted maxillary canines is shown in Figure 1. In this case, one canine is impacted lingually, and the other labially as seen on the individual sections. In this example, the additional third dimension provided by CBCT greatly increases the information available for the surgeon while planning exposure or removal. Also, adding a third dimension to the radiographic data may notably alter the information about the presence of root resorption. Currently, protocols describing the location of impacted canines using CBCT are based on reference lines both in the horizontal occlusal plane and in the mid-sagittal plane. A limitation of this method is that it uses 2-D information to quantify 3-D images.

To take full advantage of the information provided by CBCT, it is necessary to interpret volumetric images on a 3-D scale. Such a technique enables clinicians to describe and evaluate pathologies, deformities and impactions with greater detail and accuracy. The 3-D model must be reproducible and easily applied to different individuals, allowing the surgeon and orthodontist to determine the best clinical approach to treating impacted canines.

For the surgeon, knowing the precise location of the tooth provides better information as to the best possible direction of access, and may reduce the invasiveness of surgery. Obtaining an accurate 3-D spatial location of the impacted canine can help direct the surgeon/orthodontist as to what orthodontic force vector should be applied to move the canine without causing damage to adjacent teeth.

The primary aim of our study was to localize impacted canines in three dimensions and determine the most common location of impaction using CBCT. In addition, we also assessed the extent of root resorption of adjacent teeth.

METHODS

CBCT scans of 29 consecutive patients with impacted canines undergoing orthodontic treatment at UCSF Orthodontic Clinic were included in this study (CHR approval #H44601-32871-01). In 26 patients, we found bilateral impactions, and in 16 we found unilateral impactions. The age range was 10.6 to 28 years, with a mean age of 16.6 years. The individuals were scanned in an upright position using 12-inch diameter field of view (FOV) scans by the Hitachi MercuRay CBCT machine (Hitachi Medical Corporation, Tokyo, Japan) with parameters of 120 kVp, 15mA, 0.376 mm slice thickness, and a total of 512 slices in DICOM format as part of diagnostic evaluation for orthodontic treatment.

The cone beam-generated DICOM files were imported into Dolphin 3-D Imaging 10.5 (Chatsworth, California, USA) and reoriented to set the X, Y and Z planes using internal landmarks and cranial base structures. In order to precisely determine the location of the impacted teeth, we developed a coordinate system in all three planes of space. In the sagittal plane, the X-axis was set along the sella-nasion line. In the coronal plane, the line tangent to the clivus in the base of the skull was set as the Y-axis. In the axial plane, the Z-axis was defined by a line bisecting the optic foramina. The reorientation was done only once. After reorienting the image, the cusp tip of each impacted canine was selected in the volumetric view using the digitizing landmarks tool. These points were verified in the sagittal, coronal and axial views. The X, Y and Z coordinates of each digitized point were determined by the software and pasted into an electronic spreadsheet.

To determine the reliability and repeatability of this method, measurements were taken twice by the same observer (time interval = 1 day) on the original reoriented volumetric image. The position on the occlusal plane where the normally erupted canine cusp tip should be located was used as a control reference. The occlusal plane was defined as the plane touching the incisal edge of a central maxillary incisor to the mesio-buccal cusp tips of the first maxillary molars. The distal line angle of the maxillary lateral incisor and the mesial line angle of the first premolar (i.e., the teeth adjacent to the impacted canine) were projected onto the occlusal plane. The midpoint of a line joining the points of intersection was used as the reference cusp tip position. Axial, sagittal and coronal views were observed to confirm the reference point; its X, Y and Z coordinates were recorded on the electronic spreadsheet.
In our study, 40.4% (n=17) had no root resorption, 35.7% (n=15) showed slight root resorption, 14.2% (n=6) had moderate root resorption; and 4% (n=4) had severe root resorption of the adjacent lateral incisor. In only one individual was there resorption of the central incisor in addition to the lateral incisors. In this individual with bilateral canine impactions, the left central incisor showed severe signs of resorption, while the right central incisor showed slight root resorption. Sixteen had retained primary canines (38%).

STATISTICAL ANALYSIS

To determine the reliability and reproducibility of this method, all measurements were made twice by the same observer with a time interval of one day. The X, Y and Z values for the two days’ measurements of the impacted cusp tips were plotted against each other. To further study the error, we also computed Euclidean distance between the two measurements in the X, Y and Z axes. The mean difference and standard deviation (SD) of the differences for the two point sets in the X-axis were 0.31 and 0.92, respectively; in the Y-axis, they were 0.23 and 1.09, respectively; and in the Z-axis, they were 0.23 and 1.20, respectively.

RESULTS

Our method of analysis was found to be reproducible, with differences between each measurement within two standard deviations of the mean of the difference (Figure 2). Most of the individuals with impacted canines were female (76%). Palatal impactions were more common (60%).

In the X-axis, 93% (n=39) of the impactions were mesial by 10 to 15 mm; 7% (n=3) were distal impactions by 10 to 15 mm. In the Y-axis, all impacted cusp tips were located closer to the occlusal plane. In the Z-axis, 60% (n=25) of the impactions were palatal by 2 to 4 mm; 40% (n=16) were facial impactions by 0 to 4 mm. The average degree of mesial impactions was 10.1 mm (range -0.4 to 18.5 mm), and the average degree of distal impactions was 4.2 (range -1.8 to 5 mm). The average degree of the facial impaction was 4.16 mm (range 0.1 to 7.1 mm), and the average degree of palatal impactions was 1.8 mm (range -0.4 to 8.9 mm). The average degree of gingival impactions was 10 mm (range -0.1 to 21.4 mm).

In our study, 40.4% (n=17) had no root resorption, 35.7% (n=15) showed slight root resorption, 14.2% (n=6) had moderate root resorption; and 4% (n=4) had severe root resorption of the adjacent lateral incisor.

In only one individual was there resorption of the central incisor in addition to the lateral incisors. In this individual with bilateral canine impactions, the left central incisor showed severe signs of resorption, while the right central incisor showed slight root resorption. Sixteen had retained primary canines (38%).

DISCUSSION

Our main objective was to reliably assess the position of impacted canines in three dimensions and determine the most common position of the impacted canine-incisal tip, using CBCT. We used a reproducible method that describes the location of the canine in all three planes of space. The most frequent location of impacted canines was palatal, mesial and gingival.

Studies have shown that the prevalence of maxillary canine impaction varies from 0.9% to 3% in the general population. In European subjects, palatal canine impaction was found to be 2 to 3 times more frequent than facial impactions, whereas in the Asian population, facial or mid-alveolar impactions were found to be more common. The ratio for palatal impaction vs. facial impaction between European and Asian populations was found to be 5:1. Palatal impactions were more common (60%) in our study of a mixed racial population. Other studies have also found palatal impactions to be more common. In our study, similar to other studies, 76% of the individuals with impacted canines were female. Distal impactions are rarely mentioned in the literature. In our study, 7% had distal impactions.

Traditionally, the position of the impacted canine has been assessed in two dimensions: mesial/distal and buccal/palatal. Previous studies have shown that 2-D imaging using panoramic x-rays is not a reliable method for localization of impacted canines, nor is it reliable in determining the extent of possible root resorption of adjacent teeth. For more accurate localization, the position of the canine should be determined in three dimensions.

In our study, CBCT imaging allowed precise description of the impacted teeth in all three planes of space.
Previously, the spatial relationship of impacted canines was determined by using only 2-D images obtained from CBCT. Three-dimensional volumetric imaging might provide information for improved diagnosis and treatment plans and ultimately result in more successful treatment outcomes and improved patient care.

In a previous study, we have described the 3-D assessment, using CBCT, of the eruption path of the canine in individuals with bone-grafted alveolar clefts. We found that most canines on both the cleft and non-cleft side moved incisally, facially and mesially. In this study, we have described the location of the impacted canine in all three dimensions and found palatal, mesial and gingival impactions to be the most common. Furthermore, we have also described the 3-D relationship of the impacted canine to its desired final position in relation to the adjacent teeth.

CBCT, which provides a lower dose, lower cost alternative to conventional CT, is being used with increasing frequency in the practice of orthodontics and oral and maxillofacial radiology. Ludlow et al. found the calculated doses for a 12 FOV scan in mSv were NewTom3G (Elmsford, New York, USA) (45, 59), i-CAT (Hartfield, Pennsylvania, USA) (135, 193) and CB Mercuray (477, 558). These are 4 to 42 times greater than comparable panoramic examination doses (6.3 mSv, 13.3 mSv). Reductions in dose were seen with reductions in field size and mA and kV technique factors. Based on the diagnostic requirements the FOV, mA and kV can be altered to reduce the radiation dosage. In our study, we found that 38% of the subjects retained primary canines. The percentage of retained primary canines is in accordance with previous findings of 33.3% to 48.1%.

Individuals with severe lateral root resorption present treatment challenges to both orthodontists and oral maxillofacial surgeons with increased treatment time and expense. Previous studies of canine impaction-related root resorption were mainly 2-D studies and date back more than 10 years. Although our study supports previous studies showing that ectopic eruption of the impacted canine may cause root resorption of the maxillary incisors, most commonly the lateral incisors, in our study 40.4% had no root resorption, 35.7% showed slight root resorption, 14.2% showed moderate root resorption; and 4% showed severe root resorption of the adjacent lateral incisor. This is similar to the findings of Ericson et al., in which 9% had moderate resorption, but very different from his findings of 60% severe resorption. Other studies have shown root resorption to vary from 38% to 67%. CBCT allows visualization of the roots in all projections and is presumed to yield a more accurate assessment than has been obtained in the studies cited above. It is possible that we have underestimated root resorption due to inadequate visualization because the large field of view diminishes the resolution of the image (pixel size 0.377 in a 12-inch scan vs. 0.292 in a 9-inch scan). In our study, the relatively low incidence of root resorption was probably due to the low resolution of the images obtained with the CB Mercuray, which does not allow for clear depiction of resorption craters. In a study to compare the diagnostic accuracy of CBCT images of different voxel resolutions to detect simulated small internal resorption cavities, ultra- and high-resolution Iluma (Imtec, Ardmore, Oklahoma, USA) and Accuitomo (J. Morita, Kyoto, Japan) CBCT images performed similarly and better than low-resolution Iluma images in the detection of simulated internal resorption ex vivo.

**CONCLUSIONS**

We precisely assessed the position of impacted canines in three dimensions using CBCT, thereby improving accuracy of location and facilitating precise surgical and orthodontic management. In our study, 40.4% had no root resorption, 35.7% showed slight root resorption, 14.2% showed moderate root resorption; and 4% showed severe root resorption of the adjacent lateral incisor. The most frequent location of impacted canines was palatal, mesial and gingival. This method can also be applied in clinical studies to evaluate tooth movement between time-points.

References for this article can be found online at pcsortho.org, in the News and Publications/PCS Bulletin section.