# Root Resorption Detection by Multiple Radiographs versus Cone-Beam Computed Tomography

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**Abstract:**

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Purpose: To determine sensitivity and specificity of root resorption detection caused by impacted teeth using multiple traditional two-dimensional radiographs and cone-beam computed tomography (CBCT).

Methods: A convenience sample was utilized to identify pediatric patients with impacted teeth who have both CBCT imaging and multiple traditional radiographs (N = 34). Graduate dental residents specializing in pediatric dentistry or radiology reviewed the traditional radiographs and CBCT images and were asked if root resorption was present. Identification of resorption was compared to a benchmark (CBCT images reviewed by an experienced oral and maxillofacial radiologist –JA-).

Results: Five (15%) cases presented with root resorption (benchmark). When comparing 2D to 3D images, the expert reviewer had a sensitivity of 40% and a specificity of 100%. Compared to the benchmark, traditional radiographs had mean sensitivity and specificity of 47% and 85%, respectively, whereas CBCT images had mean of sensitivity and specificity 73% and 87%, respectively.

Conclusion: Root resorption with tooth impaction is not common. Multiple traditional radiographs have similar specificity as CBCT and should still initially be utilized for root resorption detection. CBCT should only be obtained if additional information, such as clarifying detailed location, is needed. This approach fits the Image Gently Campaign spirit.

**INTRODUCTION:**

Along with clinical evaluation, dental radiology is an essential component of dental exam and diagnosis. With all the added information radiographs can provide, clinicians are constantly considering the risks and benefits of exposing patients to radiation. X-rays can cause damage through ionizing DNA/RNA, proteins and enzymes, and creating free-radicals which damage cells[1]. Estimates of radiation-induced malignancies have been made through extrapolation of high-risk exposures like those who have had radiotherapy or exposed to nuclear fall-out (ex. Chernobyl), and while these estimates may not reflect low dose exposures, it has been proposed that there is a 1 in 2 million risk of an adult developing a fatal malignancy from one bitewing exposure[1]. The pediatric population is more sensitive to radiation since they are not fully matured and so prescribing radiographic imaging should be limited to what is necessary for diagnosis and its benefit should always outweigh the risk attached to the exposure[2].

The American Academy of Pediatric Dentistry has guideline recommendations for prescribing panoramic, bitewing and periapical radiographs[3]. With the increased accessibility of cone-beam computed tomography (CBCT), its applications are being more defined in dentistry in cases involving trauma, third molar extractions and oral maxillofacial surgery[4]. An obvious advantage of having a three-dimensional (3D) image is having accurate specific relations of the hard tissues, compared to traditional two-dimensional (2D) images which have superimposition of anatomical structures and may have distortions[5]. The disadvantage of 3D imaging is the higher radiation exposure. There is a wide range of effective radiation dose due to CBCT imaging, with variability depending on the field of view, resolution, and even type of machine (Amperes, Voltage and exposure time). The effective dose can be, however, as low as the equivalent of 2 panoramic radiographs.[4] Currently, evidence-based policies and guidelines are being developed by different professional organizations which may help standardize exposures. However, the latter lies in the hands of the manufacturers, who first need to agree upon the standard exposure settings for a CBCT machine.

Another area where CBCT prescription is increasing is for impacted teeth. Impacted teeth are teeth that have failed to erupt into the oral cavity, whether it is because of mechanical obstruction or lack of eruptive force. About 10% of the population have some form of impaction, with maxillary canines, wisdom teeth, and supernumeraries (teeth additional to the normal complement) being the most commonly impacted teeth[6,7]. Traditional techniques for visualizing impacted teeth involve prescribing 2D imaging from multiple angles (such as a panoramic and an occlusal radiograph) to obtain spatial information[6,8]. Spatial images of impacted teeth, whether obtained with 2D or 3D imaging, are important in treatment planning. Treatment planning options may include extraction, orthodontic repositioning into the arch, waiting for the appropriate timing, or simply leaving alone and monitoring[9]. Complications that may occur with impacted teeth include disruption of the eruption pattern of adjacent teeth, development of dentigerous cysts, and root resorption of adjacent teeth, which can compromise their vitality and prognosis[9,10].

Regardless of imaging type, radiographs should only be prescribed if “there is a diagnostic yield that will affect patient care”[3]. With this in mind, while CBCT imaging adds information and may impact treatment in certain situations, if 2D imaging is sufficient for diagnosis and treatment planning, a CBCT prescription is not indicated. Studies have shown that detecting the location (palatal, buccal) and angulation of impacted canines in 2D imaging is comparable to 3D imaging, but that root resorption detection was much less accurate[5]. External root resorption is an irreversible process resulting in loss of cementum, dentin and in severe cases, pulpal tissue with premature loss of the tooth.[11] Multiple studies utilizing CBCT to study root resorption have been described.[12,13] Accurate diagnosis of apical root resorption by periapical radiographs compared to CBCT in vitro by Ren *et al.* demonstrated that 2D imaging was not as sensitive nor as specific as 3D imaging[14]. These studies however, utilized a single 2D image when at least two radiographs at different angulations would have provided more information.

The purpose of this study is to assess whether multiple 2D images taken from different angles (applying the buccal object rule or the parallax technique) are sensitive and specific enough to detect root resorption due to impacted teeth.[6] Secondly, to describe the prevalence of root resorption due to impacted teeth in a pediatric population that can be assessed from the CBCT images.

**METHODS:**

CBCT images collected from 2011 to 2013 at the Center for Pediatric Dentistry (CPD) (University of Washington, Seattle, Washington) were assessed for impacted teeth. CBCT images will be referred to as 3D images from here on. The patient population at the CPD ranges from birth until 18 years of age, and the patients either received regular dental care at the CPD or were referred for treatment that could require obtaining a 3D image. Reasons for prescribing 3D imaging included history of trauma, extraction of third molars, oral pathology diagnosis, and orthodontic treatment. Patients with multiple 2D radiographs and a 3D image for impacted teeth were included in the study. Cases without impacted teeth and/or lack multiple 2D radiographs of the impacted teeth were excluded. This study was approved by the Institutional Review Board (IRB) from the University of Washington, Seattle, Washington (IRB-46953).

Two hundred and fifty 3D images were taken from 2011-2013, with 34 cases meeting the inclusion criteria. The images were obtained with the i-CAT Next Generation (Imaging Sciences International, Hatfield, PA, USA). The kilovoltage (kV) and milliamperage (mA) were fixed (120 kV, 5 mA) with varied volume (6 centimeter (cm) x 16 cm, 11cm x 16 cm, or 13cm x 16 cm) (height x diameter), resolution (200 micrometer (um), 300 um, or 400 um) and scanning time (8.9 seconds (s) or 23 s). The most common scan was of 13 cm x 16 cm, at 300 um resolution, and a scanning time of 8.9 seconds.

The nine examiners were graduate residents from the University of Washington in their first or second year of pediatric dental (N = 5) or oral and maxillofacial radiology (N = 4) training. Every examiner assessed the images in the same room, on the same computer at separate times, and under the same ambient light conditions. Four sets of the 2D and four sets of the 3D images were randomized separately using Microsoft Excel (2010). Each set contained all 34 cases with all images de-identified. The 2D radiographs were presented on Microsoft PowerPoint (2010), with instructions allowing adjustment of contrast, brightness and the size of images to their liking. The 3D images were viewed with InVivo5 (Anatomage, San Jose, CA, USA). Each examiner was given one randomized set of 2D images. After evaluating all of the 2D images, they were then given a different randomized set of 3D images. Examiners were never able to compare the 2D and 3D images, nor were they given any patient information. The lead researcher (KM) was present during each evaluation to answer any questions regarding the software. Examiners were instructed to assess an impacted tooth (ectopic or supernumerary) and an adjacent tooth. If more than one impacted tooth was present, a more detailed description of which tooth to assess was given (e.g. please look at the supernumerary tooth closest to the maxillary right central incisor). Each examiner was asked if the adjacent tooth had root resorption or not due to the impacted tooth. The examiners completed the assessments twice approximately one month apart.

The benchmark identification of root resorption was determined by 3D images evaluated by an experienced dental and maxillofacial radiologist who is also a pediatric dentist with over 10 years of experience (JA). JA was provided the 2D and 3D images in the same manner as the examiners.

The data was entered into REDCap (6.4.4) (Institute of Translational Health Services, Vanderbilt University, Nashville, TN, USA), and exported into Stata (12.1) (StataCorp LP, College Station, TX, USA) for analysis.

Descriptive statistics (means, standard deviations, counts, and percentages) were calculated for all patient demographic data. Sensitivity and specificity was calculated comparing 2D and 3D images for root resorption detection by the expert reviewer (JA). Sensitivity and specificity was also calculated for both the 2D and 3D images reviewed by all nine examiners compared to the benchmark. In addition, the mean and standard deviation of the nine examiners' sensitivity and specificity measures was calculated overall and by examiner type. McNemar's test was utilized to assess if there were differences in the examiner's responses at time 1 and time 2.

**RESULTS:**

Thirty-four cases fit the inclusion criteria, with the majority being female (53%). The average age of the patient was 11.7 years at the time the 3D image was taken. Twenty-two (65%) of the cases presented with supernumerary teeth, and 29 (85%) of the impacted teeth were located in the anterior aspect of the mouth. The most common 2D images received were 1 periapical and 1 panoramic radiograph (53%) (Table 1).

Of the 34 cases, 5 (15%) cases presented with root resorption. The expert reviewer correctly identified 2 of the 5 cases with root resorption using 2D images for a sensitivity of 40%, and correctly identified all cases with no root resorption (100% specificity) (Table 2).

When comparing the assessments by the examiners to the benchmark, 2D images had mean sensitivity and specificity values of 47% (standard deviation (SD= 22)) and 85% (SD = 12), respectively, and 3D images had a mean sensitivity of 73% (SD = 17) and a mean specificity of 87% (SD = 13). Radiology residents had a higher mean specificity than pediatric dental residents in 2D images, 93% (SD = 8) compared to 78% (SD= 9), but had similar mean sensitivities (45% versus 48%). Radiology and pediatric dental residents had similar mean sensitivities and specificities in the 3D images.

No significant difference was observed between answers at time 1 and time 2. This was true for all examiners.

**DISCUSSION:**

Sensitivity, or the true positive rate, describes the proportion of actual positives (root resorptions) when correctly identified. Specificity, or the true negative rate, measures the proportion of negatives that are correctly identified. In this study, specificity describes identifying no root resorption when there is no root resorption.

The authors recognize that one limitation of this study is the low number of root resorption cases (N = 5). Since a convenience sample was utilized to obtain cases for this study, it was impossible to predict how many cases would present with root resorption. Therefore, the expert's sensitivity of 40% may not necessarily indicate that it is difficult to positively identify root resorption from 2D imaging, but could be due to the small number of cases of root resorption, as missing just one case would decrease the sensitivity by 20%. This change would be less severe had we had more cases with root resorption.

In previous studies, the prevalence of root resorption from impacted canines ranged from 25.4% to 69.6%, and from mesiodens, 7.6%.[13,15,16,17,18] These values differed from the 15% prevalence in our study sample.

A study by Ericson et al. found that the use of CBCT imaging increased the detection of root resorption by 50% compared to traditional radiographs.[13] Our values are comparable with an increase in mean sensitivity from 47% to 76% for 2D compared to 3D images.

The 3D images have smaller standard deviations in sensitivity and specificity than those for the 2D images, suggesting less variability and more predictable interpretation. The added benefit of no distortion or superimposition, as well as ability to assess the images in buccal-lingual orientation may help discern root resorption when traditional radiographs are unclear (Figure 1 and 2). [9,19]

Studies have found that use of CBCT results in increased detection of root resorption, but also improves ability to localize and diagnose impacted teeth.[14,20] Orthodontic treatment plan changes as a result of the additional information provided by CBCT images have also been shown. [21,22] While some orthodontic treatment plans may proceed differently with information from CBCT imaging, most cases of root resorption remain asymptomatic. Bjerklin et al. followed patients with severely ectopic canines and found that in the majority of root resorption cases, the process of resorption does not progress once the impacted tooth has been moved orthodontically, and most affected teeth have good long term prognosis.[10] They also found that even with severely ectopic canines, in cases where root resorption is highly likely, only 61% of adjacent teeth had root resorption, showing the unpredictability of the root resorption process.[10] We found that specificity of 2D and 3D imaging is similar for root resorption. As root resorption is often unpredictable, and even when occurs, most likely present without clinical symptoms, the indication for obtaining a CBCT to assess root resorption alone is limited.

The European Academy of Dental and Maxillofacial Radiology presented a set of basic principles for the use of CBCT imaging in dentistry, with emphasis placed on needing justification for its use, and if justified, the use of lowest achievable dose while still obtaining a diagnostic image.[23] Our study shows that multiple 2D images have a true negative rate (specificity) similar to that of 3D imaging, and so should be used initially to assess root resorption, with 3D imaging indicated only if more information is needed for diagnosis. These principles are in accordance with the Image Gently campaign, and as pediatric dentists, our duty is to ensure the health of our patients.[24] The risk and benefits of obtaining not only CBCTs, but all forms of radiographs that expose our patients to ionizing radiation must be considered during our decision-making process.

Future studies may assess which types of radiographs can best identify root resorption, evaluate if there is a difference in the detection ability depending on location of root resorption, as well as determine optimized settings for root resorption detection with CBCT. In our study, the two cases positively identified for root resorption by the benchmark each had one periapical film and one panoramic film. One had resorption from the lingual aspect and the other from the buccal aspect. While our sample size is too small to draw conclusions, a larger number of positively identified root resorption cases may be able to provide clinically-applicable information on imaging prescription.

**CONCLUSION:**

1. Root resorption with tooth impaction is not common. Our study found 5 out of 34 patients with impacted teeth had root resorption.
2. Multiple traditional (2D) radiographs have similar specificity as CBCT for root resorption detection related to impacted teeth, and therefore should be utilized first.
3. CBCT should only be obtained if traditional films do not provide the necessary diagnostic information.

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Table 1. Demographic characteristics of patients with impacted teeth who received 2D and 3D imaging.

| | N = 34 |
| --- | --- |
| ***Demographic Variables*** | |
| | **Mean (Standard Deviation)** |
| Age (years) | 11.7 (2.3) |
| | **N (%)** |
| Gender | |
| Male | 16 (47%) |
| Female | 18 (53%) |
| ***Impacted Tooth Variables (Benchmark) based on the 3D images*** | |
| Supernumerary Teeth | 22 (65%) |
| Ectopic Teeth | 12 (35%) |
| Impacted Tooth Location | |
| Anterior | 29 (85%) |
| Posterior | 5 (15%) |
| ***2D Radiograph Variables*** | |
| Received 1 Periapical and 1 Panoramic radiograph | 18 (53%) |
| Received 2 Periapical radiographs | 9 (26%) |
| Received 1 Lateral Cephalometric and 1 Panoramic radiograph | 3 (9%) |
| Received 2 Periapical and 1 Panoramic radiograph | 4 (12%) |

Table 2: Sensitivity and Specificity of Root Resorption Detection of Impacted Tooth using 2D Radiographs versus 3D Images (reviewed by an experienced Oral and Maxillofacial Radiologist)

| | **3D Images (Benchmark)** | | |
|---|---|---|---|
| **2D Images** | **Root Resorption** | | |
| **Root Resorption** | **Yes** | **No** | **Total** |
| **Yes** | 2 | 0 | 2 |
| **No** | 3 | 29 | 32 |
| **Total** | 5 | 29 | 34 |
| | | | |
| | | **95% Confidence Interval** | |
| **Sensitivity** | 40% | 24% - 57% | |
| **Specificity** | 100% | 100% - 100% | |
| **Prevalence** | 15% | 3% - 27% | |

Table 3: Sensitivity and Specificity of Root Resorption Detection of Impacted Tooth by Residents using 2D and 3D Images Compared to a 3D Benchmark.

| | **Sensitivity** | | **Specificity** | |
|---|---|---|---|---|
| | **2D vs Benchmark** | **3D vs Benchmark** | **2D vs Benchmark** | **3D vs Benchmark** |
| **All Residents** | | | | |
| Mean (SD*) | 47 (22) | 73 (17) | 85 (12) | 87 (13) |
| Range (min, max) | 20, 100 | 60, 100 | 69, 100 | 59, 100 |
| | | | | |
| **Radiology** | | | | |
| Mean (SD*) | 45 (10) | 70 (12) | 93 (8) | 90 (7) |
| Range (min, max) | 40, 60 | 60, 80 | 83, 100 | 79, 97 |
| | | | | |
| **Pediatrics** | | | | |
| Mean (SD*) | 48 (30) | 76 (22) | 78 (9) | 84 (16) |
| range (min, max) | 20, 100 | 60, 100 | 68.97 | 59, 100 |

*SD = Standard Deviation

Figure 1. Example of 2D images (images on the left side) as was provided to the examiners and a screen shot from the 3D data file of the same patient (the examiners were offered the entire data file). The examiners were not able to compare the 2D and 3D files. In this case, the examiners were asked to look at the maxillary right canine and assess if it is resorbing the maxillary right lateral incisor. This is representative of a case with root resorption.

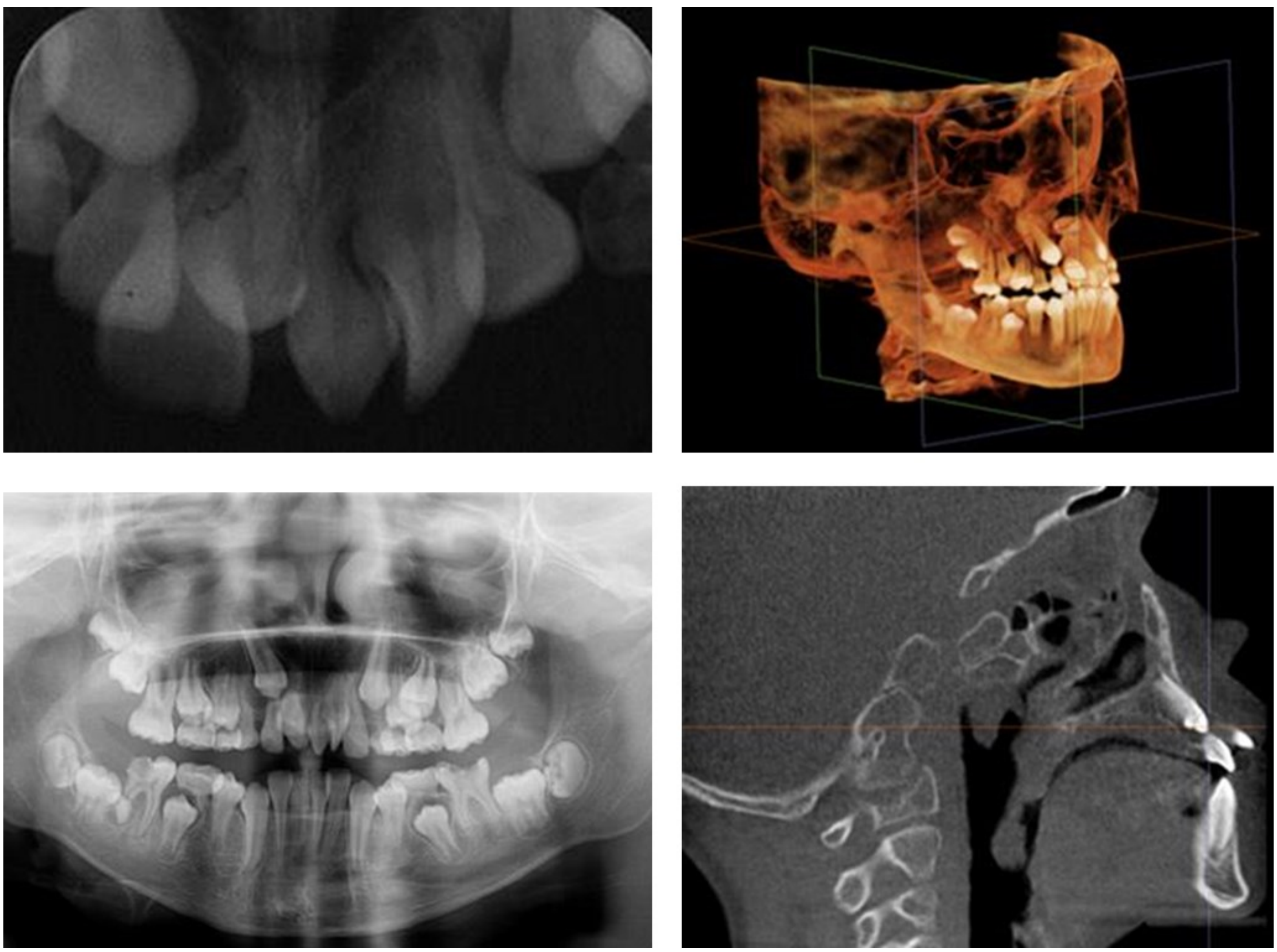

Figure 2. Example of 2D images (images on the left side) as was provided to the examiners and a screen shot from the 3D data file of the same patient (the examiners were offered the entire data file). The examiners were not able to compare the 2D and 3D files. In this case, the examiners were asked to look at the supernumerary tooth closest to the maxillary right central incisor, and assess if it is resorbing the maxillary right central incisor. This is representative of a case without root resorption.