Accuracy of angular measurements and assessment of distortion in the mandibular third molar region on panoramic radiographs

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Objective. The objective of this study was to examine distortion on panoramic radiographs by assessing the accuracy of angular measurements in the mandibular third molar region on panoramic radiographs using computed tomography (CT).

Methods. Images from patients referred to a radiology practice for low-dose CT scans of their lower third molars were used in this study. The angle between the long axes of the second and third molars was assessed on panoramic radiographs and the corresponding CT images. Apparent tilting of the tooth across the arch on the panoramic image and the bucco-lingual inclination on CT were also recorded and compared.

Results. Eighty-eight patients had 163 mandibular third molars. The mean difference between the panoramic measurements and the CT measurements was 1.44 degrees, indicating that on the panoramic radiograph the third molar appeared less mesially inclined on average. This pattern was present in most cases, but in 64 cases the third molar appeared more mesially inclined on the panoramic radiograph. It was not possible to predict the direction of the discrepancy based on the radiographic findings. The discrepancy between the 2 measurements was greater if the third molar appeared tilted across the arch on the panoramic image, and tilted teeth showed a higher bucco-lingual inclination on reformatted CT images.

Conclusions. Distortions inherent in panoramic imaging because of projection geometry produce discrepancies in the angular measurements in the mandibular third molar regions on panoramic radiographs. Interpretation of third molar angulation from panoramic radiographs is often unreliable and may not accurately reflect the true orientation of the tooth. Apparent tilting of the tooth across the arch on the panoramic radiograph exacerbates the problem and appears to correlate with the bucco-lingual inclination of the third molar as visualized on reformatted CT images. (Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;111:508-516)

Third molar development and eruption is closely monitored by dental practitioners. Assessment of third molars is often required, as third molars are reportedly the most frequently impacted teeth.1-3 Panoramic radiographs are widely used in dentistry, as they permit visualization of the dental arches and associated structures with a relatively low radiation exposure. However, owing to tomographic movement and the projection geometry, distortion is introduced into the resulting image, and this may affect interpretation of the radiograph. Furthermore, because of superimpositions and the resulting 2-dimensional image, visualized anatomy on the panoramic radiograph may not accurately represent the true anatomy of the patient. The presence of distortion in the horizontal plane is recognized, but quantification of such distortion is not readily facilitated.

Panoramic radiographs have been suggested for routine third molar examination because of frequent anomalies of third molar development, morphology, position, and eruption.4–6 When present, eruption of third molars typically occurs between the ages of 14 and 24 years.7 Third molar impaction is reported to occur in 18% to 32% of the population,8 but impaction rates of up to 40% have been noted.7 It has been reported that surgical removal of mandibular third molars is the most frequently performed oral surgical procedure.9 Given the postoperative morbidity that can occur following surgical removal of third molars, some authors have attempted to predict the likelihood of third molar eruption to ensure appropriate management and minimize unnecessary surgical removal.

Angulation of the third molar and the available space in the third molar region reportedly influence the like-
lihood of third molar eruption. Numerous researchers have measured third molar inclination and space on panoramic radiographs. Panoramic radiographs are routinely used for assessment of the third molar region in dental practices. It is important that dental practitioners are mindful of the projection geometry of panoramic radiographs and the distortion and errors inherent in this imaging modality so as to obtain optimal, accurate diagnostic information. Computed tomography (CT) has long been accepted as a highly accurate method for assessment of anatomy in all 3 planes, albeit at the expense of a significantly higher radiation dose compared with panoramic radiography. Multidetector CT and reformatted CT images permit accurate assessment of mandibular third molar angulation in the corrected sagittal and coronal planes, in addition to providing detailed and accurate information regarding the precise location of the inferior dental canal. More recently, cone beam volumetric tomography (CBVT) has proven to offer dimensionally accurate 3-dimensional information at a lower radiation dose than conventional CT.

The purpose of this study was to assess the accuracy of angular measurements made on panoramic radiographs by comparison with corresponding angular measurements made on corrected sagittal CT images. The influence of bucco-lingual inclination on the observed sagittal inclination will also be determined. Thus, distortion in the third molar region on panoramic radiographs can be assessed.

MATERIAL AND METHODS

The images examined in this study were obtained from a private radiology practice (Queensland Diagnostic Imaging, Brisbane Private Hospital, Queensland, Australia) over an 18-month period. Patients were referred for a CT scan of their mandibular third molars because the referring practitioner suspected a very close relationship between the inferior dental canal and at least one of the mandibular third molars from a panoramic radiograph. Thus, the CT images were obtained not because of the need to assess the orientation of the third molar, but because of a suspected risk of injury to the inferior dental neurovascular bundle. Scans were collected for the study only if a copy of the panoramic radiograph could be obtained and the image was deemed of suitable quality. Patients missing the adjacent mandibular second molar were not included in the study.

In total, 88 patient scans with 163 mandibular third molars were collected. Panoramic radiographs and the CT scans were de-identified and duplicated. Many, but not all of the panoramic radiographs where taken by the same radiology practice that performed the CT examinations using a variety of different panoramic machines. Cases with suboptimal panoramic radiographs or panoramic radiographs with positioning errors were excluded from this study.

Computed tomography imaging

Computed tomography scans were obtained using a multidetector CT Unit (Toshiba Aquilion, Toshiba Corporation, Tokyo, Japan) with 0.5-mm axial slices (pitch of 1.0 with 0.5-mm reconstruction interval). The scan volume began inferior to the mandibular body, extending superiorly to the middle of the ascending rami. Exposure parameters were set to 135 kV and 60 mA and a low-frequency cutoff was used in the reconstruction algorithm.

All scans were acquired in the axial plane with no gantry tilt. Reformatted images were produced by the CT technicians in the corrected sagittal and coronal planes for optimal assessment of third molar position and relationship to the adjacent inferior dental canal (as per a previous study).

Digitization of images

Panoramic films and reformatted CT images were digitized using an Epson Perfection V700 scanner with transparency adapter (Seiko Epson Corporation, Nagano, Japan). All images were scanned at 400 dpi in grayscale, and oriented the same way on the scanner to ensure consistency. Individual brightness and contrast adjustments were made before scanning to ensure optimal visibility of the third molar region. All images were saved as jpeg files at the highest-quality setting.

Evaluation of digitized radiographic images

Digitized images were imported into an x-ray viewing program (OsiriX; http://www.osirix-viewer.com; Geneva, Switzerland) on an Apple Macintosh personal computer (Apple, Cupertino, CA). Following the correction of image orientation, numerous parameters were recorded by one of the authors.

Apparent tilting of the mandibular third molars on the panoramic radiograph was assessed. The third molar was recorded as being tilted across the arch if there was separation of the buccal and lingual cusp tips on the panoramic radiograph.

The angle of inclination between the long axes of the second and third molars was recorded from the panoramic radiographs and the corrected sagittal reformatted CT images. A line bisecting the maximal mesiodistal width of the crown and a line joining the mesial and distal cemento-enamel junction defined the long axes of the molars (Fig. 1, a). The angle formed between the long axes of the second and third molars was recorded using an angle-measuring tool in OsiriX (Fig. 1, b). The mesiodistal inclination was recorded as follows: if the third molar was tilted mesially with respect to the second molar, the angle was recorded as
positive, and if the third molar was tilted distally the angle was negative. On the cross-sectional CT images the long axis of the third molar was similarly deter-
mined. A line tangent to the buccal cortex was drawn and the angle formed between the long axis of the third molar and the buccal cortex was recorded (Fig. 1, c). Inclination of the third molar toward the buccal cortex was recorded as positive and inclination away from the buccal cortex was negative. All measurements were made by the same author (R.D.) on 3 separate occasions and the author was blinded to the previous measurements.

Based on the average measured angle observed on the panoramic radiograph and the CT images, the teeth were classified using a modification of Winter’s original classification for mandibular third molars (Fig. 2).

**Statistical analysis**

All radiographic images were obtained from patients referred for CT imaging because of a perceived close relationship between the third molar roots and the associated inferior dental canal. Although it is unlikely that this relationship would influence any apparent distortion in the panoramic images, one must be mindful of the exploratory nature of this study when interpreting the results and extrapolating them to other clinical scenarios.

Linear regression analysis of the average panoramic and CT sagittal angulations (the angle formed between the long axes of the mandibular second and third molars) was performed to confirm a direct relationship. Subsequent analysis using the paired Student t test to test for similarity of the measurements was performed. The measured difference between the panoramic and CT sagittal angulations was correlated with the measured cross-sectional angulation of the third molar (measured on the cross-sectional CT images). Furthermore, the observation of tilting of the third molar on the panoramic radiograph was correlated with the measured cross-sectional angulation.

**RESULTS**

Eighty-eight patients with 163 impacted mandibular third molars referred for CT examination were used in this study. There were 61 females with 110 third molars and 27 males with 53 third molars. Most patients presented with bilateral mandibular third molars. Only 13 cases were unilateral: 12 female and 1 male. The average age was 32 years with a range of 17 to 62 years. The distribution of ages was roughly similar for males and females.

From the panoramic radiograph, 88 teeth were observed to be tilted (T) across the arch, and 75 did not appear to be tilted (NT). A slightly higher proportion of tilted teeth was found in males (58.5% compared with 51.8% in females).

From the panoramic radiographs, 22 teeth were disto-angular, 47 were vertical, 73 were mesio-angular, and 21 teeth were horizontal. Classification from the
CT recorded similar findings: 22 teeth were disto-angular, 47 teeth were vertical, 72 teeth were mesio-angular, and 22 teeth were horizontal (Table I). Further analysis revealed that 4 teeth recorded as being disto-angular on the panoramic radiographs were actually vertical on the CT. Additionally, 4 teeth that were vertical on the panoramic radiograph were disto-angular on the CT. Likewise, 5 teeth recorded as being
vertical on the panoramic radiograph were mesio-angular on CT, and 5 teeth that were mesio-angular on the panoramic radiographs were vertical on the CT. Three teeth classified as being mesio-angular on the panoramic images were horizontal on the CT, and 2 that were horizontal on the panoramic radiographs were in fact mesio-angular on the corresponding CT images.

Simple linear regression confirmed the presence of a direct linear relationship between the panoramic angular measurements and the corresponding CT angular measurements (Fig. 3). The Pearson correlation coefficient (R) was 0.9858 ($R^2 = 0.9719$), indicating a significant positive correlation between the 2 measurements. The average difference between the panoramic measurements and the CT measurements was –1.44 degrees (SD = 5.75 degrees), indicating that overall the third molar appeared less mesially inclined on the panoramic radiograph compared with the corrected sagittal CT images. The mean for third molars on the right was –1.39 degrees and the mean for third molars on the left was –1.49 degrees, and a 2-sample Student $t$ test returned a $P$ value of .9118, indicating that this difference was not significant. The high standard deviation suggested that there is considerable variation in the difference between the angular measurements on the 2 imaging modalities.

As the primary objective was to assess similarity between the panoramic and CT angular measurements in the mandibular third molar region, the paired Student $t$ test was used. A $P$ value of .0017 was observed indicating that there are statistically significant differences between the angular measurements obtained from the panoramic radiographs and the reformatted CT images. Further investigation revealed that for 99 cases the third molar was less mesially oriented on the panoramic radiograph, with a mean angle of –5.03 degrees (Fig. 4). The remaining 64 cases showed a more mesial inclination of the third molar on the panoramic radiograph, with a mean angle of 4.12 degrees (Fig. 5). Thus, the overall magnitude of the difference between the angular measurements is between 4 and 5 degrees, but the direction of the change is variable. No correlation between the direction of change and either the measured panoramic or CT angulation was observed.

The bucco-lingual inclination of the third molar as measured on the cross-sectional CT images was plotted against the difference between the average panoramic and CT angular measurements (Fig. 6), and linear re-

Table 1. Classification of third molars from panoramic radiograph and CT

<table>
<thead>
<tr>
<th>Classification</th>
<th>DA ($-70$ to $-10$)</th>
<th>V ($-10$ to $+10$)</th>
<th>MA ($+10$ to $+70$)</th>
<th>H ($&gt; +70$)</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panoramic radiograph</td>
<td>22</td>
<td>47</td>
<td>73</td>
<td>21</td>
<td>163</td>
</tr>
<tr>
<td>CT</td>
<td>22</td>
<td>47</td>
<td>72</td>
<td>22</td>
<td>163</td>
</tr>
</tbody>
</table>

CT, computed tomography; DA, disto-angular; H, horizontal; MA, mesio-angular; V, vertical.
gression analysis was performed. No strong association was found, and the Pearson correlation coefficient (R) was 0.1617 ($R^2 = 0.0262$).

Apparent tilting across the arch of the third molar on the panoramic radiograph was recorded against the difference between the observed average panoramic and CT angulations. A mean difference of $-1.16$ degrees was recorded for the teeth that did not appear to be tilted, and the $P$ value of 0.0631 suggests that this difference is only just not statistically significant. For teeth that were apparently tilted, a mean difference of $1.68$ degrees was observed, and the calculated $P$ value of .0118 suggests that this difference is significant. The average cross-sectional angulation was calculated for teeth that did not appear to be tilted across the arch and those that did. The average cross-sectional angulation for the 75 teeth that did not appear to be tilted was $-10.83$ degrees, whereas the average cross-sectional angulation for the 88 teeth that did appear to be tilted was $-17.97$ degrees (Fig. 7). A 2-sample Student $t$ test produced a $P$ value of .0009, indicating that this difference is significant.

**DISCUSSION**

Panoramic radiography is widely accepted as the imaging modality of choice for assessment of mandibular third molars, owing to the large area of visualized tissues, excellent patient acceptance, and relatively low radiation exposure. However, inherent distortions introduced owing to the image projection geometry may affect subsequent interpretation, and in critical cases insufficiently accurate information is obtained. The increased availability of multidetector CT and cone beam tomography, and the dimensionally accurate nature of the reformatted images provides practitioners with the highest quality diagnostic information, but with increased radiation exposure and at a higher financial cost.
cost. Thus, panoramic radiography is usually the first choice for radiographic assessment of impacted third molars, in spite of its limitations.

Many authors have attempted to perform detailed assessments of third molars on panoramic radiographs.\textsuperscript{16-26} Assessment of space in the third molar region, third molar

Fig. 6. Scatter plot of the difference between the panoramic and CT angles against the bucco-lingual inclination measured on cross-sectional CT (with regression line).

Fig. 7. a, Thirty-eight not showing signs of tilting on the panoramic image. b, The same tooth on the cross-sectional CT image appears upright. c, Tilted appearance of 48 on the panoramic image. d, Lingual inclination of the 48 on the cross-sectional CT image. B, buccal; Li, lingual.
angulation and position, the anatomic relationship with the inferior dental canal, and the prediction of third molar eruption have all been discussed. However, there appears to be little consensus regarding the relative accuracy of angular measurements in the mandibular third molar region despite the fact that numerous authors perform such measurements routinely. It is not uncommon for dental practitioners to subjectively assess the inclination of the third molar during radiographic interpretation, so the purpose of this study was to assess the relative accuracy of angular measurements made in the mandibular third molar region on panoramic radiographs, using the corresponding dimensionally accurate reformatted CT images for comparison. It is important to note that CT examinations were performed because of a suspected close relationship between the third molar roots and the adjacent inferior dental canal. CT was used, as cone beam tomography scanners were not available in local imaging centers, and referring surgeons favored the high-quality images printed on radiographic film produced by CT scanning. Furthermore, scan protocols were optimized to reduce patient radiation exposure, and scan field of view was heavily limited to avoid unnecessary radiation exposure. The apparent influence of observed tilting of the third molar across the arch on the panoramic radiograph and the bucco-lingual inclination observed on the reformatted CT images were also considered.

A mean difference of $-1.44$ degrees (SD = 5.75 degrees) was noted between the angular measurements made on panoramic radiographs and corrected sagittal CT images. This indicates that on average the panoramic radiograph underestimated the mesial inclination of the third molar. The observed $P$ value of .0017 indicates that this difference is statistically significant. No significant difference was observed based on the side of the third molar ($P = .9118$). The relatively large standard deviation suggests that there is considerable variability in the direction and magnitude of the discrepancy between the angular measurements made on the 2 modalities. Further examination revealed that 99 teeth were less mesially inclined on the panoramic radiograph (mean angle of $-5.03$ degrees, SD = 3.70 degrees), and 64 teeth were more mesially inclined (mean angle of 4.11 degrees, SD = 3.50 degrees).

An overall discrepancy of 4 to 5 degrees between angular measurements made on panoramic radiographs and reformatted CT images is similar to the findings of other authors. Sant’Ana et al. observed a 5.37-degree discrepancy in their study, and Peck et al. noted a difference of 3.59 degrees between panoramic radiographs and CBVT. Interestingly, these studies noted that panoramic radiographs always overestimated the mesial inclination of the mandibular third molar, which is in contrast to the findings in this study. This may be because of the sample size in this study being significantly larger than in these previous studies, or that panoramic images from many (unidentifiable) machines taken by many operators were assessed in this study. Previous studies with small samples assessed images from a single panoramic machine only (usually taken by a single operator). It seems that the panoramic image may project the third molar with either a more mesial or less mesial inclination, although overall the panoramic radiograph seemed to underestimate the true mesial inclination.

Bucco-lingual inclination as observed on cross-sectional CT images and observed tilting across the arch of the mandibular third molar on the panoramic radiograph were correlated with the difference between the angular measurements in the third molar regions. Teeth that appeared tilted across the arch on the panoramic radiograph, as described by separation of the buccal and lingual cusp tips on the panoramic image, exhibited a higher mean difference between the angular measurements made on the panoramic image and CT image. The mean difference for tilted teeth was $-1.68$ degrees, whereas the mean difference for teeth that were not tilted was $-1.16$ degrees. A $P$ value of .0118 suggests that the mean difference for tilted teeth is statistically significant and therefore teeth that appear tilted across the arch on the panoramic radiograph are more likely to be projected at an aberrant angle. The observation of tilting on the panoramic image was also correlated with the measured bucco-lingual inclination on the cross-sectional CT images. The mean bucco-lingual inclination of the teeth that appeared tilted on the panoramic radiograph was $-17.97$ degrees, compared with a mean inclination of $-10.83$ degrees for teeth that did not appear tilted. Once again, the $P$ value of .0009 indicates that this difference is significant, and there is reasonably good correlation between the tilted appearance on the panoramic radiograph and the bucco-lingual inclination observed on CT images.

Very few previous studies have assessed the effect of bucco-lingual inclination on the panoramic third molar angulation. The finding that altered bucco-lingual inclination has some effect on the observed panoramic angulation is consistent with findings in previous studies. It is difficult to quantify the effects in a clinical study like this one, but it appears that teeth with severe bucco-lingual inclination are projected with a significantly altered angulation on the panoramic radiograph. Thus, care should be exercised when interpreting the mesio-distal inclination of third molars on panoramic radiographs where there are signs of apparent tilting of the third molar across the arch.

Given the variable accuracy with which panoramic radiographs project the orientation of mandibular third molars, practitioners should be aware that radiographic...
observations may not always correlate precisely with the clinical findings. The tooth may be more mesially or less mesially inclined than is apparent on the panoramic image. Furthermore, if the apparent inclination differs markedly from the actual orientation of the tooth, assessment of the likelihood of eruption may be unreliable. Assessment of the mesial/distal orientation of lower third molars is more likely to be inaccurate when the tooth appears tilted across the arch on the panoramic radiograph. Tilting on the panoramic image seems to indicate bucco-lingual tilting of the tooth but the direction of the tilt cannot be determined. The observation of tilting is also likely to alter the planned surgical technique. It seems that angular classifications based solely on panoramic radiographs do not accurately reflect the true classification in some instances. Although it is neither practical nor advisable to commit all patients with unerupted mandibular third molars to a CT scan, care is required when interpreting the findings in the third molar region on panoramic radiographs. Panoramic radiographs are still useful for preliminary assessment and determination of the need for further imaging. With the increasing availability of CBVT and the continual reductions in radiation exposure with successive generations of CBVT scanners and CT scanners, it may soon be practicable to routinely request accurate 3-dimensional information about impacted teeth to better facilitate diagnosis and treatment planning.

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REFERENCES


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