Abstract: We measured the gonial angle (GA) on panoramic radiography (PR) and analyzed the correlation between the GA on PR and lateral cephalometric radiography (LCR). In total, 49 PR films and LCR films from dentate young adults were evaluated. Orthodontists plotted four points (articulare, menton, posterior gonion, and lower gonion) on the PR and carefully traced them. Using a protractor, two radiologists measured the GA on LCR images. A simultaneous experimental study of two dry skulls was performed to compare the GA on LCR and PR. The GA was slightly smaller on the PR of the dry mandible than on the LCR and tended to decrease continuously with magnitude toward the Frankfort horizontal plane. The mean GA was 115.1 ± 5.2° on PR and 122.2 ± 6.4° on the LCR. The values were highly correlated (Pearson product-moment correlation coefficient, 0.801). The GA on PR was nonsignificantly smaller than that measured on LCR. The difference may be due to head position, the inclination angle of the mandibular body, and/or the direction of the incident X-ray beam. (J Oral Sci 57, 373-378, 2015)

Keywords: gonial angle; panoramic radiography; lateral cephalometric radiography; Frankfort horizontal plane.

Introduction

The gonial angle (GA) on lateral cephalometric radiography (LCR) represents mandibular morphology with respect to the mandibular ramus and mandibular body and is important in forecasting growth (1-4). Panoramic radiography (PR) is useful for diagnosing panoptic jaw lesions and changes in anatomical landmarks, such as the condition of the mandibular angle and ramus width, width of cortical bone in the inferior border of the mandible, and the development of calcification in the oral cavity or cervical region (5). If the GA is expressed as angulation of the mandibular angle on PR, it is useful to examine how it relates to the GA on LCR. Some reports found that occlusal force is related to the morphology of mandibular angles and reflects the size of the GA (6-11). However, these findings may not be sufficient to change prosthodontic practice. PR is useful in diagnosing dento-maxillofacial lesions and assessing systemic disease. Observation of the GA while confirming absence of overlap between the two sides is an important clinical tool.

Many studies have evaluated the GA on PR, but no previous report described how to produce accurate, detailed images of the GA (9,11,12-20). It is essential to develop a detailed method for drawing the inferior border of the mandible—in which only one line is made
on the inferior border of the mandible—so as to not change the condition of the GA. Additionally, if the GA on PR is anatomically similar to the GA on LCR or has a characteristic structure, PR may prove to be more useful and could become a high-value-added dental examination. Thus, using a novel method, we examined the utility of measuring the GA on PR and the correlation between the GA on PR and LCR. The GA differs between these imaging modalities because of differences in the image-forming processes of PR and LCR. In addition, interpretation of the GA on PR is likely related to head positioning, and images of the mandibular form change with the location in the image layer, the pitch of the focus, and the inclination of the examined mandible.

Materials and Methods
Preliminary experiment using dry skulls for PR and LCR
Using two dry skulls, we altered the GA by positioning the skulls on fixed bases. The skulls were placed on an acrylic table by choosing the fault surface on a Vera-viewepocs Panoramic X-ray device (Morita Co., Kyoto, Japan) operated at 75 Kvp, 1 mA, and 17 s, using a Kodak direct-view computed radiography (CR) cassette (Fig. 1). The angulation of the dry skull was adjusted to one of five levels (-10 to +10) against the Frankfort horizontal plane (FH). The exposed cassette was scanned by a Direct View classic CR system (Carestream Health Japan Co. Ltd, Tokyo, Japan). LCRs of the dry skulls were simultaneously obtained with a KXO-50R DRX-1603B device (Toshiba Corp., Tokyo, Japan) operated at 60 Kvp, 10 mA, and 0.061 s.

These images were carefully traced on tracing paper. Four points (articulare [Ar], menton [Me], posterior gonion [PGo], and lower gonion [LGo]) were plotted—particularly, the comparable points on PR and LCR (Fig. 2)—and measured by two orthodontists, using a protractor. These four points were needed in order to clearly and correctly draw the mandibular bone. The Ar on PR is defined as the intersection between the posterior
border of the condylar process and the line of the basilar portion of the occiput. Me is the point at the intersection between the mandibular midline and the inferior border of the mandible. PGo is the prominent point of the mandibular ramus. LGo is deep depressed point of the lower border of the mandible. Accordingly, GO is equidistant from the PGo and LGo. Go is the midpoint, ie, the bisector of the angle of intersection between the ramus plane (linear Ar-PGo) and mandibular plane (linear Me-LGo).

PR and LCR films of identical participants
A total of 49 PR films of healthy volunteers with no maxillofacial conditions were used. The 49 participants comprised 34 men and 15 women (mean age 24.3 years; age range, 22-35 years). PR and LCR films from the same participants were compared.

The films were taken parallel to the FH in the Vera-viewepocs, exposed at 75 Kvp, from 10 mA to 7 mA and 17 s using a Kodak direct-view CR cassette. The exposed cassette was scanned by the Direct View classic CR system. LCRs were obtained by using a Veraview 102md AECP-1901 device at 75 Kvp and 8 mA. These images were accurately traced on tracing paper, and four points (Ar, Me, PGo, and LGo) were identified by two orthodontists (Observer 1: 4 years of experience; Observer 2: 7 years of experience, PhD) (Fig. 3). Later, one radiologist (37 years of experience, radiology specialist) measured these GAs on tracing paper.

This study was approved by the Ethical Committee of Nihon University School of Dentistry (2012-9) and consent was obtained from the all volunteers.

Statistical analysis
The study data were analyzed with SPSS for Windows, version 17.0 (IBM Japan Inc., Tokyo, Japan), and descriptive statistics were calculated with Excel 2013 (Microsoft, Inc. Tokyo, Japan). GA measurement was done twice, with an interval of 1 month, and Dahlberg’s formula (21) was used to determine intraobserver reproducibility. The

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**Table 1** The GA on PR and LCR images of the dry skull

<table>
<thead>
<tr>
<th>Angle</th>
<th>PR Right</th>
<th>LCR Right</th>
<th>PR Left</th>
<th>LCR Left</th>
</tr>
</thead>
<tbody>
<tr>
<td>FH -10</td>
<td>112.0°</td>
<td>112.5°</td>
<td>114.5°</td>
<td>114.0°</td>
</tr>
<tr>
<td>FH -5</td>
<td>111.0°</td>
<td>112.0°</td>
<td>114.0°</td>
<td>114.0°</td>
</tr>
<tr>
<td>FH ±0</td>
<td>110.5°</td>
<td>110.5°</td>
<td>116.5°</td>
<td>119.5°</td>
</tr>
<tr>
<td>FH +5</td>
<td>108.0°</td>
<td>108.0°</td>
<td>112.5°</td>
<td>110.0°</td>
</tr>
<tr>
<td>FH +10</td>
<td>105.5°</td>
<td>105.5°</td>
<td>110.0°</td>
<td>109.0°</td>
</tr>
</tbody>
</table>

GA: Gonial angle, PR: panoramic radiography, LCR: lateral cephalometric radiography
Wilcoxon signed-rank test and Pearson product-moment correlation coefficient were used to compare the GA on PR and LCR images from the 49 participants.

### Results

In the dry skulls, for angles less than -10°, when the pitch of the angle varied, the GA on PR gradually approached that on LCR (Table 1). Thus, the FH plane setting of the dry skull may be approached with a downward tilt on PR relative to that on LCR. Thus, the present findings showed that the GA was significantly smaller on PR than on LCR, as determined with Dahlberg’s formula, namely 0.46° on PR and 0.23° on LCR.

For the 49 participants, the mean GA was 122.2 ± 5.2° (range, 101.5° to 126.5°) on LCR and 115.1 ± 6.4° (107.3° to 134°) on PR (Table 2). The difference was significant ($P < 0.01$, Wilcoxon signed-rank test). Additionally, in regression analysis the Pearson product-moment correlation coefficient was 0.801 ($R^2 = 0.642$) for the GA on LCR and PR (Fig. 4). The regression line obtained from this correlation coefficient was $Y = 0.645X + 7.616$.

### Discussion

PR was recently shown to be a convenient tool for obtaining information on systemic diseases. It appears to be very useful for diagnosing osteoporosis (22-26) and for identifying and evaluating cervical anomalies (27-30). Previous studies used anatomical landmarks of cephalometric points to evaluate the 3D morphology of cone beam CT in vivo, in which landmark identification with 3D technology is equal in clinical reliability to standard 2D cephalometric analyses (31). The results showed that age and systemic factors, as well as tooth loss, may change the GA (3,4,32-35). However, as compared with LCR, PR is not yet reliable enough to provide sufficiently accurate additional information (4). In addition, no reports have specified a detailed method for drawing the inferior border of the mandible (9,11-20). Thus, the important points for tracing on film were reviewed in this report. We believe that improved measurement is needed in order to ensure a clear understanding of GA values. The present study clarified the decision related to the connection between the ramus plane and the mandibular plane. The latter is of particular importance because only one line was drawn on the inferior border of the mandible, due to the changing characteristics of the GA.

Previous studies attempted to predict the accuracy of the GA obtained from PR images. It is important to evaluate the similarity of the GA on PR and LCR. PR has several advantages over LCR, including the ability to evaluate mandibular asymmetry (4,12) and mandibular growth direction (2-4,35,36), the separate and clear measurement of both the right and left GA (12,20), relatively low radiation exposure (37-39), and the possibility of greater clinical versatility. It has been reported that the GA is wider for edentulous persons than for dentate individuals (6-11), perhaps because of morphological changes secondary to tooth loss. However, the shapes of the mandibular base and GA correlated with the function and shape of the muscles of mastication in some reports (37,40,41). Other studies (42,43) showed that masticatory muscles change with age, with decreased contractile activity, and with lower muscle density, as compared with dentate persons, and that the masseter and medial pterygoid muscles undergo greater age-related decreases because of their insertion into the region of the GA. The present study did not examine the effect of age on masseter muscles, as the focus was evaluation of the GA on PR. The present study included 49 healthy adults aged 22-35 years with no maxillofacial conditions. The mean GA was slightly lower than that reported in other populations, perhaps because of the positions of the two points on the inferior border of the mandible, or to the small

### Table 2 Angulation of the GA on LCR and PR images from 49 participants

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>LCR-GA</td>
<td>122.2°</td>
<td>5.2</td>
<td>101.5-126.5°</td>
</tr>
<tr>
<td>PR-GA</td>
<td>115.1°</td>
<td>6.4</td>
<td>107.3-134.0°</td>
</tr>
</tbody>
</table>

GA: Gonial angle, PR: panoramic radiography, LCR: lateral cephalometric radiography
sample size.

In the experimental study, for angles less than -10°, when angle pitch was varied, the GA on PR gradually approached that on LCR, the FH plane setting of the dry skull corresponded to a downward tilt on PR, relative to that on LCR. In dry skulls, this could cause displacement between the ear canal and the point of the external acoustic foramen. That is, the FH plane of the human body has different dimensions when attempting to match a point of the external acoustic foramen to the FH plane setting of a dry skull, with a slight difference between the external acoustic foramen and ear canal in the human body. Thus, the angle approached a downward tilt of -10° to the FH plane.

Comparisons of the GA on PR and LCR did not previously consider the formation of the GA angle. The GA in PR is based on tomography, while the GA on LCR is a simple lateral view. Therefore, the GA on PR might not represent all data present on LCR. Thus, the LCR might provide a clearer GA angle. On PR, the form and thickness of cortical bone in the mandibular can affect the size of GA, and the inclination angle of the mandibular body affects the incident X-ray directly. In this study, a regular FH plane was maintained when performing X-ray examination, which differed from the procedure used in clinical studies.

The 49 participants were healthy volunteers, and the mean GA was 122.2 ± 5.2° on LCR and 115.1 ± 6.4° on PR. This discrepancy may have been due to the small number of participants (49). However, to identify and plot the necessary four points (Ar, Me, PGo, and LGo) in future studies, only one anatomical baseline needs to be drawn on the inferior border of the mandible while varying the condition of the GA. This will enable an accurate relationship between the ramus plane and mandibular plane to be established for GA determination.

This study measured the GA on PR images and the correlation between the GA on PR and LCR images. Future research using the GA on PR will increase the accuracy of GA assessment. However, measurement of the GA on PR is complicated by the inclination angle of the mandibular body and the direction of the incident X-ray beam, and these difficulties need to be addressed. The usefulness of PR is sometimes exaggerated, but it is certainly suitable for initial diagnosis. It is therefore likely that its use will increase.

Acknowledgments
This study was supported by a Grant from the Sato Fund, Nihon University School of Dentistry (2013) and a Grant from the Dental Research Center, Nihon University School of Dentistry (2014). This study was supported by a Grant from the Dental Research Center, Nihon University School of Dentistry (2014) and a Grant from the Sato Fund, Nihon University School of Dentistry (2013).

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