ORIGINAL RESEARCH

Effect of Head Positioning in Panoramic Radiography on Vertical Measurements – An *In Vitro* Study

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ABSTRACT

Objective: The objective of the study was to assess whether it is possible to make accurate vertical measurements of the jaws from panoramic radiographs.

Materials and Methods: Five dry skulls were shifted 5 mm forward and backward and tilted 5° up and down in the sagittal plane. Panoramic radiographs of each skull were obtained in nine different positions. In the maxilla, three reference lines were used and vertical measurements were made at the distal surfaces of the first premolar and first molar and in the midline. In the mandible, measurements were made at the distal surfaces of the first premolar and first molar, and at the mental foramen on both sides, and in the midline. The points and lines were marked manually and the radiographs were digitized, magnified, and measured.

Results: Sagittal shifting and tilting had only a slight effect on measurements in the mandible. Sagittal tilting of the head had the greatest effect on all the measurements made from the line between the articular eminences to the alveolar crest, as well as measurements in the maxillary midline.

Conclusions: The line between the articular eminences is unsuitable as a reference line for measurements of the tooth-bearing areas. A slight misalignment of the head does not significantly affect the vertical measurements in the mandible or of the posterior maxilla if the reference lines are in the same vertical plane as the teeth.

Keywords: Head positioning, Panoramic, Radiography, Sagittal shifting, Vertical measurements.

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INTRODUCTION

The value of any diagnostic procedure depends on the amount and validity of the information that can be derived from it. There are several reasons for panoramic radiography's popularity including increased overall coverage of the dental arches and associated structures, the relatively undistorted anatomic images produced, reduced radiation dosage to the patient, and the simplicity of operation.[1] Panoramic films are useful for evaluating skeletal and dental pathology, making a dimensional assessment and determining relative angulations of teeth with other structures.[2-4] Recently, the panoramic radiography has become important in implantology for assessing the height of the residual ridge and a variety of reference lines have been used for this purpose, but the effect of head positioning on the subsequent measurements has not been taken into account.[5] The most frequent errors in panoramic radiography occurred in patient positioning. In conventional panoramic radiography, the thickness of the image layer is greater in the posterior regions of the jaws than in the anterior. Blurring and distortion are least in the center of the image layer. Failure to position, the patient's dental arches accurately causes variation in both vertical and horizontal magnification, and although vertical magnification differs only slightly with displacement from the center of the image layer, the resultant variation in the horizontal magnification is obvious. In the clinical situation, the complexity of human facial morphology, the fact that vertical distances at different sites of the maxilla or mandible subtend different angles to the film planes and individual deviation in anatomy, may all lead to errors in measurements.[6-9] Hence, the present study is an attempt to evaluate the effect of head positioning in panoramic radiography on vertical measurements.

MATERIALS AND METHODS

The study was conducted in the Rays Diagnostic and Imaging Center Bengaluru, Karnataka.[5] Dentate dry skulls were obtained from the Anatomy Department of Kempegowda Institute of Medical Sciences and Department of Oral Pathology V. S. Dental College and hospital, Bengaluru, India.

The following materials were used in the study: In the pre-radiographic phase, five dentate dry skulls and metallic balls of 2 mm diameter were required. Moreover, in the radiographic phase, Digital Panoramic and Cephalometric Radiologic unit (KODAK 8000 radiographic and dental diagnostic unit), controlled from a PC interface, face to face positioning with the digital sensor of charge-coupled device (CCD) + optic fiber sensor was used in the present study. The dimensions of the matrix were 2500 × 1244 pixels with a gray scale of 4096–12 bits. The focal spot of the X-ray tube was 0.5 mm (IEC 336). Total filtration was > 2 mm eq/Al. The magnification factor of the machine was 1.27.

The output is processed on a personal computer (Pentium 4, 2.8 GHz,) by the proprietary software (Trophy DICOM, Mater viewer 4.2.2). The skulls were positioned on a panoramic unit with the help of a plastic head holder and a metal tripod stand. All measurements were done with the mouse-driven cursor on the computer monitor screen with the help of appropriate software (Master viewer 4.2.2).

Pre Radiographic Phase

Five dry skulls were used in this study with complete dentition. Metal balls of 2 mm diameter are fixed with dental wax as markers at the maxillary and mandibular alveolar crest in the midline (between central incisors) and the alveolar crest present between the first and second premolar and first and second molars of both sides.

Frankfort horizontal plane (FHP)was marked on the dry skull using a lead pencil and ruler, +5° and −5° horizontal lines were drawn using protractor from FHP.

The skulls were oriented on the panoramic machine with the help of radiolucent plastic head holder and a metallic tripod stand and were positioned with three plane light positioning system of the panoramic unit.

Radiographic Phase

The skulls were positioned so as to simulate the normal position of the patient's head in the panoramic apparatus. A bite block was placed between the edges of the central incisors in an edge-to-edge position. Nine panoramic radiographs were taken for each of the skulls in the following positions:

1. FHP parallel to the horizontal plane (0°) with no shift, 5 mm forward shift (+5 mm), and 5 mm backward shift (–5 mm).
2. FHP tilted 5 forward (+5°) with no shift, 5 mm forward shift (+5 mm), and 5 mm backward shift (–5 mm).
3. FHP tilted 5° backward (–5°) with no shift, 5mm forward shift (+5 mm), and 5 mm backward shift (–5 mm).

The positions of the skulls (0° and 0 mm) were calibrated using the three-plane light-positioning system of panoramic apparatus [Figure 1]. A Kodak 8000 digital panoramic unit controlled from a PC interface was used with CCD and optical fiber sensor as an image receptor.

The exposure parameters (electric factors) used for the procedure were the lowest one established for this equipment for the respective procedures (for panoramic radiograph) it was set at 60 kVp 2 mA and 13.9 s. An aluminum filter of 2 cm was placed in front of the equipment collimator diaphragm for both the radiographic procedures, to impede film overexposure, due to the absence of soft tissue.

Statistical Methods

The statistical software, namely SPSS 15.0, Stata 8.0, MedCalc 9.0.1, and Systat 11.0 was used for the analysis of the data and Microsoft Word and Excel have been used to generate graphs, tables, etc. Results on continuous measurements are presented on Mean ± standard deviation (SD) (Min-Max) and results on categorical measurements are presented in number (%). Significance is assessed at 5% level of significance. Analysis of variance has been used to find the significance of study parameters between different positions. Coefficient of variations has been computed in the present study.

RESULTS

All the vertical measurements on the panoramic radiographs were done with mouse-driven cursor with the help of software. Vertical measurements were made from the alveolar crest of **the** first molar, first premolar**,** and incisors to the reference lines

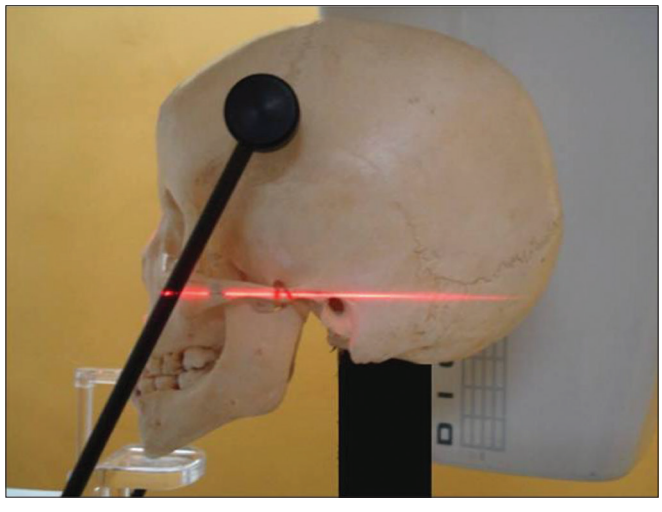

Figure 1: The skulls (0° and 0 mm) were calibrated using the three-plane light-positioning system

joining the most inferior points of both orbital margins (Lo), the line joining the most inferior points of both articular eminences (La) and the line joining the most inferior margins of the zygomatic process (Lz) in maxilla. In the mandible, a line was drawn joining the lowest point of the angle and lower border. Measurements were made perpendicular to this line in the posterior region. Entire data obtained were entered in a master chart, tabulated, and analyzed statistically.

Observations

Visibility of the anatomical structures in the radiographs

The orbital margins, the most inferior points of both articular eminences, the most inferior margins of the zygomatic process and inferior margin of the nasal cavity in the maxilla.

Results – while mental foramen in the mandible was well demarcated, in all the panoramic radiographs. Since the coefficient of variation (CV) did not show any

Table 1: Effect of positions on radiological measurements in maxillary molars

	0°			+5°			−5°			*P*
	0 mm	**+5 mm**	**−5 mm**	**0 mm**	**5 mm**	**−5 mm**	**0 mm**	**+5 mm**	**−5 mm**	
Distance from max. molars to Lo (A)										
Mean±SD	32.22±3.37	32.71±3.80	33.12±3.60	32.91±3.69	33.60±4.14	33.11±3.28	31.34±3.74	31.95±3.66	32.27±3.35	0.992
CV%	10.45	11.62	10.87	11.22	12.31	9.90	11.94	11.45	10.37	
Distance from max. molars to La (B)										
Mean±SD	28.17±2.58	28.66±2.76	28.21±2.72	25.01±2.36	23.61±3.19	24.49±3.45	34.30±3.59	34.06±3.76	34.02±4.09	<0.001**
CV%	28.17	28.66	28.21	25.01	23.61	24.49	34.30	34.06	34.02	
Distance from max. molars to Lz-C										
Mean±SD	18.36±2.53	18.52±2.71	18.74±2.63	18.33±1.92	17.97±2.11	16.91±2.00	17.71±1.48	17.44±2.16	17.97±1.81	0.941
CV%	13.80	14.62	14.06	10.50	11.75	11.80	8.36	12.37	10.09	

SD: Standard deviation

Table 2: Effect of positions on radiological measurements in maxillary premolars

	0°			+5°			−5°			*P*
	0 mm	**+5 mm**	**−5 mm**	**0 mm**	**5 mm**	**−5 mm**	**0 mm**	**+5 mm**	**−5 mm**	
Distance from max. premolars to Lo (A)										
Mean±SD	35.51±2.38	35.15±2.47	35.77±2.42	34.66±2.74	34.69±2.62	34.29±2.22	36.01±2.87	35.98±2.63	36.22±2.47	0.927
CV%	6.69	7.03	6.78	7.89	7.55	6.47	7.96	7.31	6.82	
Distance from max. premolars to La (B)										
Mean±SD	30.51±2.08	30.35±2.07	30.60±2.56	26.17±2.20	24.34±3.42	25.39±3.80	38.96±3.06	38.34±3.20	38.34±3.40	<0.001**
CV%	6.83	6.83	8.36	8.41	14.07	14.99	7.84	8.35	8.87	
Distance from max. premolars to Lz-C										
Mean±SD	20.65±1.46	21.10±1.94	21.47±1.75	20.76±2.67	19.17±1.79	18.39±2.07	22.87±2.22	22.28±2.43	22.52±2.72	0.033*
CV%	7.09	9.18	8.15	12.87	9.32	11.25	9.72	10.92	12.07	

SD: Standard deviation

Table 3: Effect of positions on radiological measurements in maxillary incisors

	0°			+5°			−5°			*P*
	0 mm	**+5 mm**	**−5 mm**	**0 mm**	**5 mm**	**−5 mm**	**0 mm**	**+5 mm**	**−5 mm**	
Distance from max. central incisors to Lo (A)										
Mean±SD	36.28±2.95	35.51±3.07	36.08±2.69	34.49±2.63	34.06±2.48	34.10±2.19	38.35±3.33	38.85±3.94	38.46±3.07	0.066+
CV%	8.13	8.64	7.47	7.63	7.27	6.42	8.68	10.13	7.98	
Distance from max. central incisors to La (B)										
Mean±SD	30.24±1.48	30.79±1.63	30.92±1.99	25.59±1.92	25.13±3.15	24.51±3.53	39.92±2.78	39.20±2.80	39.65±3.29	<0.001**
CV%	4.91	5.29	6.44	7.51	12.55	14.41	6.96	7.15	8.31	
Distance from max. central incisors to Lz-C										
Mean±SD	20.93±1.43	19.65±1.57	20.46±1.52	18.81±1.16	18.11±1.47	18.11±1.67	24.96±3.58	24.62±4.25	24.84±3.99	<0.001**
CV%	6.82	7.97	7.42	6.19	8.14	9.23	14.35	17.27	16.06	
Distance from max. central incisors to floor of nasal cavity-(D)										
Mean±SD	20.95±4.00	20.61±3.87	21.11±3.29	21.67±3.72	21.12±3.71	20.95±3.91	22.82±4.01	23.32±4.22	23.14±4.15	0.930
CV%	19.11	18.76	15.58	17.19	17.56	18.65	17.58	18.12	17.95	

SD: Standard deviation

significant difference between right and left side, the average value of both sides was used at the first premolar and molar site maxilla and mandible.

Evaluation of vertical measurements in the maxilla

In the maxilla, there was a significant association between sagittal tilting and vertical measurements (B) made from the line joining the articular eminences [Tables 1-3]. At all maxillary sites, these B measurements were affected more by sagittal tilting compared with A, C, and D ($P < 0.001$). The vertical measurements (A, B, and C) made from all three reference lines were more sensitive to sagittal tilting in the midline than were the measurements made in the premolar and molar regions($P < 0.001$). In contrast, sagittal shifting had only minor effects on any of the value measured.

The CV values are shown in Tables 1-3. At the first premolar sites, the A measurements were significantly less affected by tilting and shifting than C. This difference was not significant at the molar sites. In the midline, the C measurements showed a greater variation than A and D.

Evaluation of vertical measurements in the mandible

In the mandible, the influence of the head position on the X, Y, and Z distances was within the range, and the mean values of CV were <2.0% at all sites measured. The CV values did not show any statistical differences between the five skulls.

DISCUSSION

The purpose of this radiographic study was to assess the change in vertical measurements caused by tilting and shifting the head, not to calculate the radiological heights.

When an object is placed perpendicular to the central ray, its projected height is at a maximum. When the same object is inclined towards the film or toward the tube, its projected height in a panoramic radiograph will decrease non-linearly with respect to the angle of tilt. The mandibular body is more or less perpendicular to the central ray in the panoramic machine; the FHP is parallel to the horizontal plane. Since the skulls are not tilted sideways, and the reference lines were situated more or less below the points being measured, slight sagittal tilting had little effect on the measurements in mandible.[5] The present study showed that in the maxilla, all measurements made from the lines joining posteriorly situated articular eminences were most sensitive to tilting; such a line is unsuited as a reference line for measurements in tooth-bearing areas since it is actually in the base of the skull. In the anterior maxilla, measurements made from all three reference lines were more affected by tilting than were those in the posterior region, since these lines are not in the same vertical plane as the anterior teeth. These above findings are consistent with the results of the previous studies carried out to evaluate head positioning using dentate dry skulls.[5] It would, therefore, be unwise to use these in the future as reference lines for measurements in this area. With respect to the combined effect of shift and tilt, in the maxillary first molar area, measurements from the reference lines Lo and Lz did not show any significant difference in terms of coefficient of variation. In the maxillary first premolar area and the midline, measurements from the Lz, which was drawn through more posterior points than Lo, did show a significant variation. Sagittal shifting had little effect on the measurements in the mandible and maxilla, a fact in agreement with the result of previous studies.[3-5] Although the present study was carried out using the digital panoramic unit in contrast with other studies, performed with film-based radiography did not show significant variation in results compare to previous studies.[5] This may be due to the fact that digitization increases only image quality in terms of brightness, contrast, and image enhancement but it does not alter the measurements. In the present study, sagittal tilting which was limited to 5° did not significantly affect the vertical measurement in the posterior maxilla and mandible which was also noticed in a previous similar study.[5] While significant errors were noticed in all measurements in other studies, when the occlusal plane was tilted up anteriorly by 8°[3] A panoramic radiograph is a distorted, two-dimensional representation of the three-dimensional object. It has a curved, sharply depicted layer, with other parts of the object being to a greater or lesser degree blurred. This should always be borne in mind when embarking on the difficult task of making measurements from panoramic radiographs. Vertical measurements should only be made using reference points and lines that are located anatomically directly above or below the point being measured, in the plane as the center of the image layer.[5,10] The panoramic X-ray machine (KODAK 8000 radiographic and dental diagnostic unit) used in the present study has a patient-positioning system with a bite block, temple support, and patient positioning lights in three planes. In clinical practice, the Frankfort plane is usually within a range of ±5°. Tilting the patient's head by 5° is less likely to occur when using the bite block than the chin support alone. An accidental sagittal shift of 5 mm is likely with bite block and chin rest. However, with this degree of shift and tilt the radiographs will still be diagnostically acceptable, on sagittal shifting a little blurring and horizontal widening or narrowing will be apparent

in the image of anterior teeth but a nonsignificant variation in vertical measurements are observed. Frankfort Horizontal plane (FHP) is utilized as reference for head positioning since it was recommended by manufacturer. Significant good results were obtained. However, it was found in a few studies that good images of teeth in both jaws can also be obtained by keeping the occlusal plane parallel to the horizontal plane.[5,11] The sagittal shifting was carried out using an inbuilt device in panoramic unit showing from −5 mm to 0 to +5 mm marking with 1 mm precision allowing accurate sagittal shifting. Metallic balls of 2 mm diameter are used in the present study as a radiopaque marker at the alveolar crest, and the measurements were made from coronal end of the balls which helped to avoid inter-observer examination variation which significantly affected SD in previous studies in which no such markers were used.[5] The all vertical measurements in the present study were done with the help of mouse-driven cursor on the computer monitor screen, thus eliminating the need to digitize the film radiograph after marking the points with pencil, or manual measurements directly on radiographic film. The all vertical measurements in the present study were done with the help of mouse-driven cursor on the computer monitor screen, thus eliminating the need to digitize the film radiograph after marking the points with pencil, or manual measurements directly on radiographic film, though a similar study showed that it is possible to achieve a precision of 0.06 mm by digitally magnifying radiographs. However, the points to be measured were marked with a pencil in the unmagnified original radiographs, as a result of which the actual accuracy of measurements had a large SD.[5] A slight misalignment of the head which occurs frequently in everyday practice does not significantly affect vertical measurements in the posterior mandible or maxilla or the anterior mandible, as long as the reference lines are in the same vertical plane as the teeth. For this reason, measurements in the anterior maxilla are unreliable. Sagittal shifting had little effect on the measurements in the mandible and maxilla.[12-14] With 5° of tilting and 5 mm shifting the radiographs will still be diagnostically acceptable, even though a little blurring and horizontal widening or narrowing will be apparent in the image of anterior teeth. The line between the articular eminences is unsuitable as a reference line for measurements of the tooth-bearing areas.[15]

CONCLUSIONS

A slight misalignment of the head which occurs frequently in routine practice does not significantly affect vertical measurements in the posterior mandible or maxilla, or the anterior mandible, as long as the reference lines are in the same vertical plane as the teeth. Sagittal shifting had little effect on the measurements in the mandible and maxilla. Measurements in the anterior maxilla are unreliable. The line between the articular eminences is unsuitable as a reference line for measurements of the tooth-bearing areas; hence, this should not be taken as a reference line in future studies for assessment of vertical measurement in panoramic radiography.

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