Evaluation of Dimensional Accuracy of Panoramic Cross-Sectional Tomography, Its Ability to Identify the Inferior Alveolar Canal, and Its Impact on Estimation of Appropriate Implant Dimensions in the Mandibular Posterior Region

Anshul Mehra, BDS, MDS, FAGE;* Keerthilatha M. Pai, BDS, MDS†

ABSTRACT

Objectives: To evaluate the dimensional accuracy of panoramic cross-sectional tomography, its impact on implant size estimation and its ability in identifying the inferior alveolar canal in the mandibular posterior region.

Material and Methods: Eight partially edentulous mandibles with 18 edentulous sites were obtained. Orthopantomograms and tomograms were made and the mandible's outline and the position of mandibular canals on tomograms were traced on a clear acetate paper. Horizontal and vertical magnification factors were calculated. The mandibular height, distance between mandibular canal and alveolar crest, maximum bucco-lingual width, distance between buccal cortex and mandibular canal, and cortical thickness at the inferior border of the mandible were measured. Potential implant sites were identified and implant sizes were estimated. Location and visibility of mandibular canals were also evaluated. The mandibles were sectioned at each site and all the above mentioned parameters were assessed which served as gold standard.

Results: Mean horizontal and vertical magnification factors were 1.47 ± 0.048 and 1.53 ± 0.038. Total height and maximum bucco-lingual width were underestimated by 1.88% and 1.59%. Crest to canal distance, cortical thickness at the inferior border of the mandible and buccal cortex to mandibular canal were overestimated by 0.59%, 5.16%, and 3.64%. Implant sizes were estimated for 11 sites and changes were recorded at 2 sites between record 1 and record 2. However, there was no disagreement between record 2 and record 3. Of the canals, 61.11% were located lingually and the visibility of mandibular canals was poor in 44.44% of cases.

Conclusions: The tomograms were found to be accurate for the measurements in both horizontal and vertical planes and reliable for implant size estimation, taking into consideration proper magnification factors. They were also found to be useful in assessing the location of mandibular canal but were not very effective in discerning it.

KEY WORDS: cross-sectional tomography, implant dentistry, panoramic radiography, radiographic examination

INTRODUCTION

Implant therapy is accepted as an integral part of dental practice. The long-term clinical results of implant therapy largely depend on accurate presurgical diagnosis and treatment planning. The goal of presurgical treatment planning in dental implantology is to enable the positioning of optimum number of implants of optimum size, keeping in mind the location of vital anatomical structures, especially the inferior alveolar canal, mental foramen, floor of the maxillary sinus, submandibular gland fossa, and the nasal fossa. In a

*Senior lecturer, Department of Oral Medicine and Radiology, U.P. Dental College and Research Centre, Faizabad Road, Lucknow, Uttar Pradesh, India; †professor and head of department, Department of Oral Medicine and Radiology, Manipal College of Dental Sciences, Manipal, Karnataka, India

Reprint requests: Dr. Anshul Mehra, 701-A, Kalyan Apartment, Sector-24, Indira Nagar, Lucknow-226016, Uttar Pradesh, India; e-mail: mehraanshul@yahoo.co.in

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position article by the American Academy of Oral and Maxillofacial Radiology, it was recommended that some form of cross-sectional radiography should be part of treatment planning as it provides vital information for the optimal placement and alignment of the endosseous implants, thus reducing surgical discomfort, numbers of procedures and expense to the patient.[1] Cross-sectional information can be obtained through a variety of techniques like conventional tomography, including linear and multi-directional systems, computed tomography, and magnetic resonance imaging.

Recently, panoramic x-ray machines have been introduced, which produce cross-sectional images with curved layer linear tomography. Few studies have been performed to evaluate how accurate curved layer tomography is in terms of linear measurements in the posterior region of the mandible.[2–5] In these studies, the magnification factors for the panoramic cross-sectional tomograms given by the manufacturers were taken into consideration and the actual values were calculated. The magnification factors specified by the manufacturers correspond to an average jaw size and shape and the ideal positioning of the patient in the machine. As there can be a wide variation in the jaw sizes and shapes and also there can be some error in positioning the jaws in the machine, the magnification factors for each site should be calculated separately to avoid any measurement error. However, this point was not considered in any of these studies. Moreover, its ability to identify the inferior alveolar canal and the impact of this technique on the estimation of appropriate implant dimensions has also not yet been evaluated.

The aim of the present study was to evaluate the dimensional accuracy of curved layer panoramic cross-sectional tomography, its ability to identify the inferior alveolar canal and its impact on estimation of appropriate implant dimensions in mandibular posterior region.

MATERIAL AND METHODS

Eight partially edentulous mandibles with 18 posterior edentulous sites (4 second premolars, 10 first molars, and 4 second molars) were obtained from the Department of Anatomy, Kasturba Medical College, Manipal. All the edentulous sites were delineated and the centers of all the edentulous sites were marked by indelible pencil perpendicular to base of the mandible. A ball bearing of 4.5 mm diameter embedded in wax was placed at edentulous site on the central line marked, contacting the alveolar ridge. These steel balls served as radiopaque markers for identification of edentulous sites on radiographs and also to calculate horizontal and vertical magnification factors for each radiograph.

Panoramic radiographs of the mandibles and tomograms of each edentulous site were then made with Planmeca Proline 2002CC (Planmeca Oy, Helsinki, Finland). Four aluminium plates of 1.2 mm thickness each were secured on the tube head to simulate soft tissue scatter and to obtain clinically acceptable film density and contrast. Panoramic radiographs were made following imaging equipment manufacturer's protocol.

Tomograms were made using transversal slicing hardware and software package. Image layer thickness of 4 mm was chosen and the automatic program (P 60) was used for acquiring the images. The automatic program took three exposures of the region of interest and between each exposure the patient positioning mechanism moved the patient by 4 mm. Mandible was positioned in the transversal head support or jig (Figure 1) such that the inferior border of the mandible was parallel to the floor. The target positioning knob was adjusted so that the central line marked on the edentulous site (region of interest) was aligned with the clear acrylic plate (Figure 2). The angle adjusting knob was adjusted until the line tangential to the curve of the jaw at the region of interest was parallel to the mid-sagittal plane positioning light (Figure 3). The centering knob was adjusted so that the center of the region of interest was aligned with the mid-sagittal plane positioning light (Figure 4). The exposure values used were 60 kVp, 4 mA, and 18 seconds exposure time. All the radiographs (panoramic radiographs and tomograms) were acquired with Kodak Lanex Regular screens and T-Mat G film (Eastman Kodak, Rochester, NY, USA) and were processed using automatic processor (Promax x-ray film processor).

The following criteria were used to evaluate the tomographic images for acceptability:[6,7]

(1) anterior–posterior and transversal positioning should be correct; (2) contrast and density of the radiograph should be correct; (3) there should be no blurriness in the radiograph; (4) localization marker (steel ball) should be visible on each tomographic cut for identification of the location of the cut; (5) shape of alveolar ridge crest should be demonstrated; and (6) inferior alveolar canal should be appreciable. If canal was not identifiable, the inferio-superior position of canal was estimated on panoramic radiograph relative to

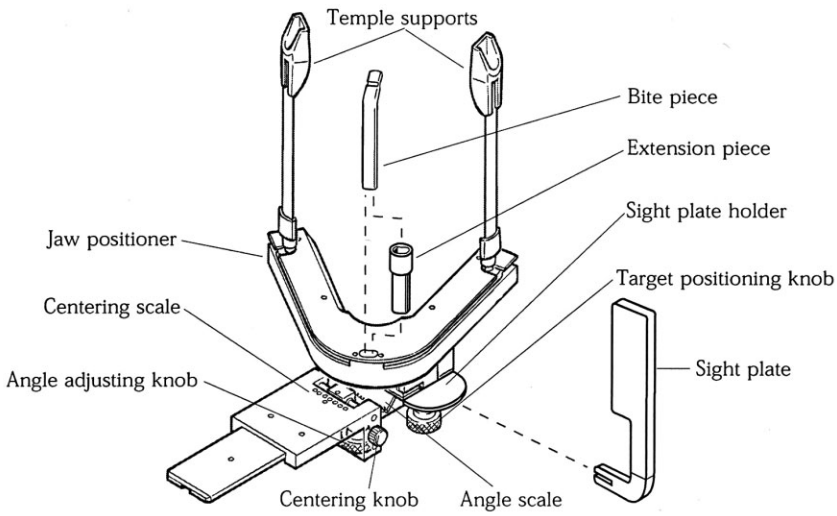

Figure 1 Transversal head support, 254 × 164 mm (150 × 150 DPI).

edentulous site and tomogram was visually scanned for evidence of oval radiolucency approximately 2.8 mm in diameter at that distance.[8]

All the radiographs made fulfilled these criteria. The tomographic cut corresponding to the region of central line marked on the edentulous site (i.e., the second image on the tomogram out of the three) was chosen for the evaluation. The outline of the mandibles and the position of the inferior alveolar canals on the tomograms and panoramic radiographs were traced on a clear acetate paper under ideal viewing conditions. The inner cortical plates seen on the tomograms were also traced.

Quantitative Evaluation

The magnification factors for tomograms were calculated in both horizontal and vertical planes by measuring the diameter of the ball bearing on the tomograms and dividing it with the actual diameter (4.5 mm). For panoramic radiographs, the magnification factor (1.2) given by the manufacturer was taken into consideration. Actual measured values ($D_{measured}$)

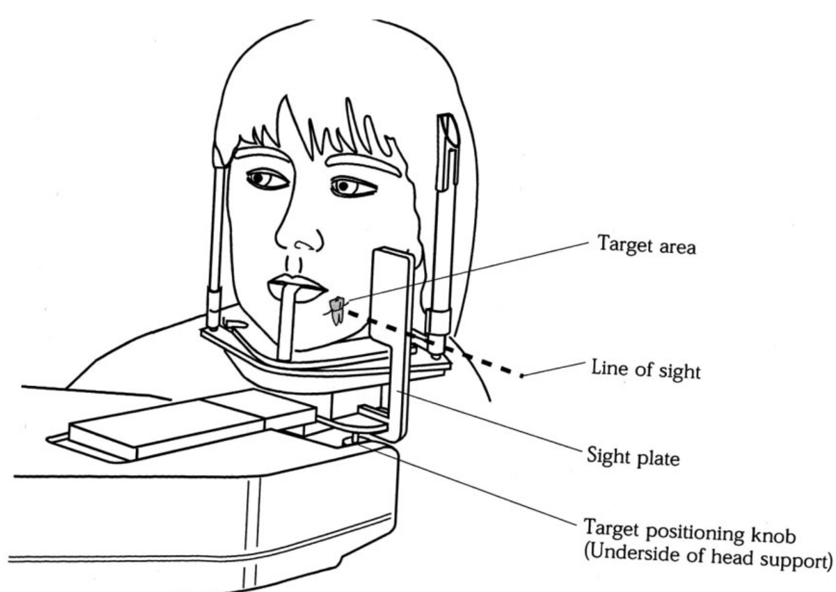

Figure 2 Region of interest aligned with clear acrylic plate, 254 × 170 mm (150 × 150 DPI).

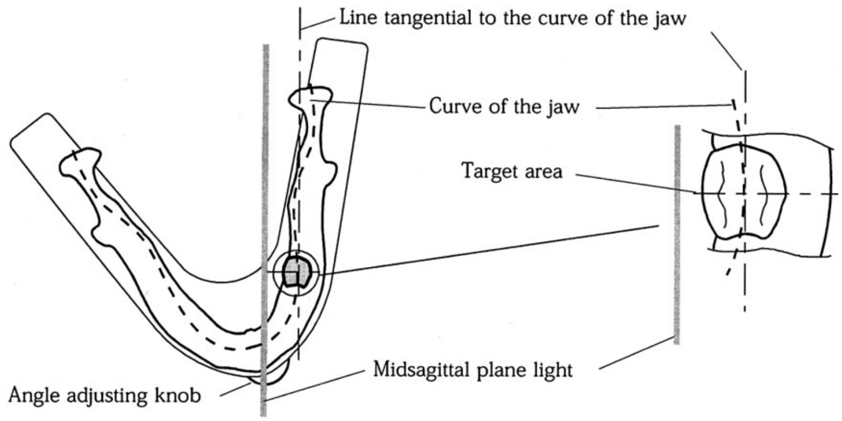

Figure 3 Line tangential to the curve of the jaw at the region of interest was made parallel to the mid-sagittal plane positioning light by adjusting the angle adjusting knob, 254 × 131 mm (150 × 150 DPI).

were calculated by dividing the measured values with their respective magnification factors.

On the tracings of the tomograms, following measurements were made: (1) overall mandibular height; (2) distance between inferior alveolar canal and the alveolar crest; (3) maximum bucco-lingual width; (4) cortical thickness at inferior border of mandible; and (5) distance of the inferior alveolar canal from the buccal cortex (Figure 5).

On the tracings of the panoramic radiographs, following measurements were made: (1) the mesio-distal distances at edentulous site; and (2) the distances between inferior alveolar canals and the alveolar crests at the center of the edentulous sites were measured (Figure 5).

On intact mandibles, following measurements were made: (1) the mesio-distal distances at edentulous site; and (2) maximum bucco-lingual widths along the central line marked at the edentulous sites were measured.

Mandibles were then sectioned at 90° to inferior border of mandible along the central line marked at each edentulous site using a precision saw and following measurements were made on the sectioned mandibles, which served as gold standards: (1) overall mandibular height; (2) distance between inferior alveolar canal and the alveolar crest; (3) maximum bucco-lingual width; (4) cortical thickness at inferior border of mandible; and (5) distance of the inferior alveolar canal from the buccal cortex (Figure 5).

All these measurements were done using vernier calipers to the nearest of 0.01 mm by an oral radiologist having experience with implant treatment planning. For evaluating the dimensional accuracy of panoramic cross-sectional tomograms, all the measurements made

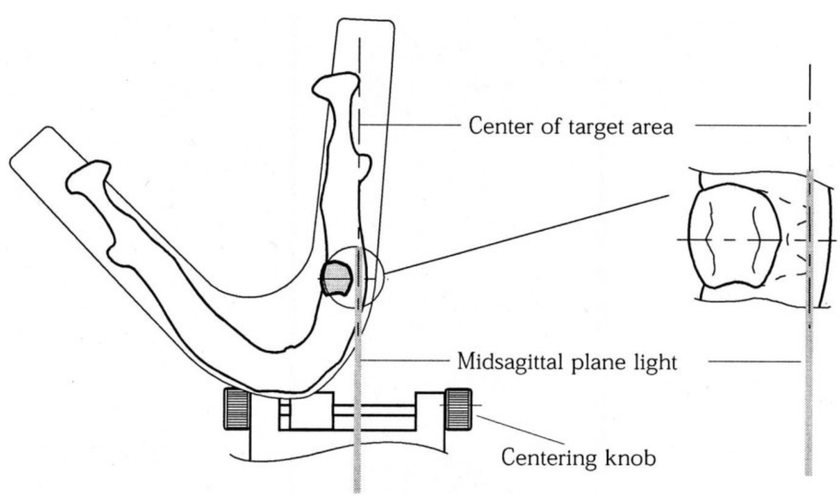

Figure 4 Center of the region of interest was aligned with the mid-sagittal plane positioning light by adjusting the centering knob, 254 × 159 mm (150 × 150 DPI).

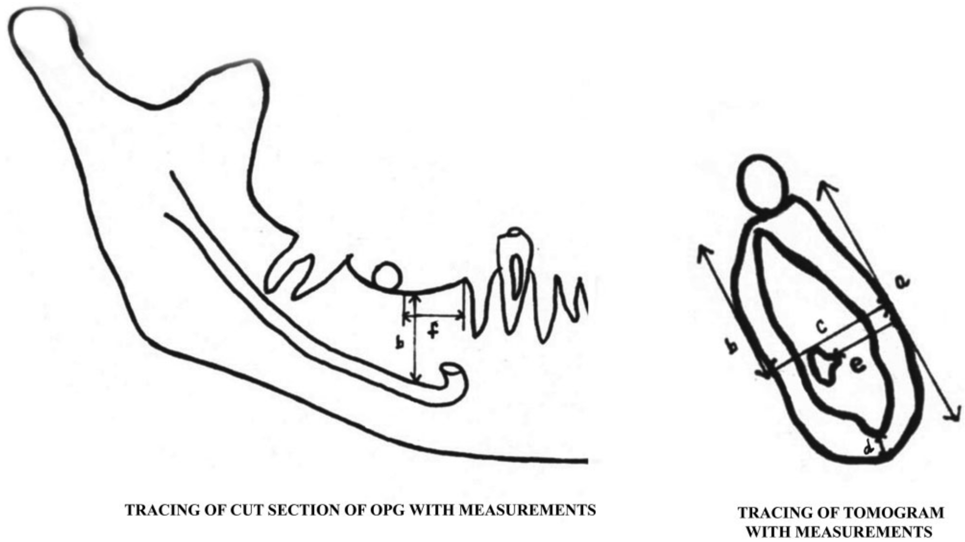

Figure 5 Measurements done on the tracings of OPGs and Tomograms. a = total mandibular height, b = distance between mandibular canal and alveolar crest, c = maximum bucco-lingual width, d = cortical thickness at the inferior border of the mandible, e = distance of mandibular canal from the buccal cortex, and f = mesio-distal distance. 297 × 209 mm (300 × 300 DPI).

on the tomograms were compared with the gold standards. For the estimation of implant dimensions, following measurements done on the tomograms, panoramic radiographs, intact mandibles, and sectioned mandibles were taken into account: (1) distance between inferior alveolar canal and the alveolar crest; (2) maximum bucco-lingual width; and (3) mesio-distal distance at edentulous site.

Orientation and Appearance of Inferior Alveolar Canal on the Tomograms

The inferior alveolar canals were identified on the tomograms. The orientation of the canals were classified into buccal, central, and lingual and their appearances were classified as good, fair, poor, and invisible.[9] The orientations of the inferior alveolar canals on the sectioned mandibles were also classified into buccal, lingual, and central and these findings served as gold standards (Table 1).

Estimation of Implant Dimensions

All the edentulous sites were screened and the potential implant sites were identified on the basis of the following inclusion criterion: the alveolar bone at each potential implant site should atleast have: (1) 6 mm bucco-lingual width (along the line marked at the center of the edentulous site); (2) 8 mm mesiodistal width of the edentulous site; and (3) 10 mm alveolar bone above the inferior

TABLE 1 Classification for the Appearance of Inferior Alveolar Canals on Tomograms and Orientation of Inferior Alveolar Canals on Tomograms and Sectioned Mandibles[9]

Appearance of inferior alveolar canal on tomogram	Good	The whole circumference of bony wall clearly visible.
	Fair	The canal wall partly visible.
	Poor	The canal is identifiable but with no cortication.
	Invisible	Canal is not identifiable with certainty.
Orientation of inferior alveolar canal	Lingual	Distance between the canal and lingual bone is at least 1 mm less than the distance between the canal and buccal bone.
	Central	Distance between the canal and lingual bone is equal to the distance between the canal and buccal bone.
	Buccal	Distance between the canal and buccal bone is at least 1 mm less than the distance between the canal and lingual bone.

alveolar canal (at the center of the edentulous site). These measurements were made on intact mandibles and on the panoramic radiographs. On the basis of the above-mentioned criterion, only 11 sites were identified as potential implant sites. Three sites were excluded because of inadequate height and four sites were excluded because of insufficient bucco-lingual width. A proforma was made which described the protocol for estimating the implant dimensions (see Appendix). Following this protocol and the measurements done on the radiographs (tomograms, panoramic radiographs) and mandibles (intact and sectioned mandibles) as described previously, the implant dimensions were estimated as follows:

Record 1 – Implant dimensions were estimated by the measurements made on panoramic radiographs and on intact mandibles.
Record 2 – Implant dimensions were estimated by the measurements made on panoramic radiographs and tomograms.
Record 3 – Implant dimensions were estimated by direct measurement on intact and sectioned mandibles.

Record 1 and record 2 were compared with record 3, which served as gold standard. The dimensions of the implants were estimated according to Frialit-2 implant kit (Dentsply Friadent, Postfach, Mannheim, Germany).

STATISTICAL ANALYSIS

The statistical analysis was conducted through use of SPSS software for Windows (Standard version release 11.0.1, LEAD Technologies, Haddonfield, NJ, USA).

Magnification Factors

The mean horizontal and vertical magnification factors for the tomograms were calculated.

Linear Measurements

For evaluating the dimensional accuracy of panoramic cross-sectional tomograms, the differences from the gold standards for the linear measurements made on the tomograms were determined using the paired *t*-test with a two-tailed alternative hypothesis and 95% confidence interval. The results were considered significant if $p \leq .05$. Percentages of mean differences from mean of direct measurements were also calculated.

Identification of Inferior Alveolar Canal

The agreement percentages between the findings on tomograms and sectioned mandibles for the orientation of the canal were calculated and the correlations between these findings were analyzed using Spearman's bivariate correlation coefficient test. For the appearance of the inferior alveolar canal on the tomograms, the percentages of canals in each group (i.e., good, fair, poor, and invisible) were calculated.

Intraexaminer Reproducibility and Interexaminer Variability

To estimate the intraexaminer reproducibility and interexaminer variation, 10 edentulous sites were randomly selected and the radiographs were evaluated after an interval of 7 days by the same examiner for intraexaminer variability and by another observer, an oral implantologist, for interexaminer variability.

For the linear measurements done on the tomograms, the differences from the gold standards were determined using the paired *t*-test with a two-tailed alternative hypothesis and 95% confidence interval. The results were considered significant if $p < .05$. The implant dimensions were also estimated for these sites and the differences, if any, were noted. For the orientations and appearances of the inferior alveolar canals on the tomograms, Spearman's bivariate correlation coefficients and agreement percentages were calculated.

RESULTS

The mean horizontal magnification factor for tomogram was found to be 1.47 ± 0.048 and the mean vertical magnification factor for tomogram was found to be 1.53 ± 0.038 as compared with 1.45 mentioned by the manufacturer.

Comparison of the mean differences showed that there were no statistically significant differences between the measurements made on tomograms and the gold standards. The mean values, percentage difference from the gold standards, range of differences, and the range width of the measurements using 95% confidence interval limit are summarized in Table 2. Interexaminer and intraexaminer variability for the above-mentioned measurements were analyzed and there were statistically no significant differences in the measurements.

A total of 61.11% of the canals were located lingually, 16.67% were located buccally, and 22.22% were located centrally. There was 77.78% agreement for orientation of inferior alveolar canal with good correlation between the findings on the tomogram and the gold standard (0.639) (Table 3). The appearance of inferior

TABLE 2 Comparison of the Measurements Done on the Tomograms with the Gold Standard

		Mean[†] (mm)	Mean of Difference (mm)	% Difference from Direct	95% Confidence Interval of the Difference		Range Width (mm)	Sig. (p value)*
					Lower (mm)	Upper (mm)		
Total heights	Tomogram	23.86	−0.456	−1.88	−0.930	0.017	0.94	0.058
	Direct	24.316						
Distance between inferior alveolar canal from the crests	Tomogram	13.468	0.079	0.59	−0.358	0.516	0.874	0.707
	Direct	13.388						
Maximum bucco-lingual width	Tomogram	12.03	−0.194	−1.59	−0.416	0.27	0.69	0.082
	Direct	12.227						
Cortical thickness at inferior border of mandible	Tomogram	3.038	0.149	5.16	−0.138	0.437	0.575	0.288
	Direct	2.888						
Distance between buccal cortex and the inferior alveolar canal	Tomogram	5.355	0.188	3.64	−0.002	0.379	0.381	0.052
	Direct	5.166						

The mean values, mean of differences, percentage difference from the gold standards, range of differences and the range width of the measurements using 95% confidence interval limit has been shown.
*$p \leq .05$.
†$n = 18$.

alveolar canal was good in 16.67%, fair in 16.67%, poor in 44.44%, and invisible in 22.22% (Table 4). For the orientation of inferior alveolar canal, the interexaminer reproducibility showed a good correlation coefficient of 0.713 with 80% agreement percentage and intraexaminer variability showed a good correlation coefficient of 0.645 with 70% agreement percentage (Table 5). For the appearance of inferior alveolar canal, the interexaminer reproducibility showed a very good correlation coefficient of 0.918 with 80% agreement percentage and intraexaminer variability showed a very good correlation coefficient of 0.877 with 80% agreement percentage (Table 6).

Table 7 shows the estimated implant sizes for the 11 potential implant sites. There was a change in the estimated implant size at two sites (5 and 11) between record 1 and record 2. The same disagreement was present (site no. 11) when examined by the second observer and also by the same observer after an interval of 1 week. However, there was no disagreement between record 2 and record 3.

DISCUSSION

Panoramic cross-sectional tomography is a curved layer linear tomography present in some of the panoramic imaging systems. Planmeca 2002CC with Transversal Slicing System was used in the present study. This system uses narrow beam tomography in which the image layer is situated behind effective axis of rotation in the back beam area and axis of rotation is situated between image layer and film. The film moves in the direction opposite to that when taking the panoramic radiograph. The actual width of image layer is 40 mm and the angle of swing is 50°. Positioning of the patient in the head supporting system or jig is simple and easy especially for the posterior region. In the anterior region, the space available between the tubehead and the jig is reduced, as the jig is rotated by 90° to position the region of interest in the in-focus image layer. So it becomes quite difficult to position a bulky patient in the jig for making the cross-sectional image of the anterior region. The program is limited to axially corrected cross-sectional images of either 4 or 8 mm thickness. In 8 mm thick layer, there is loss of image sharpness and thus error in the measurements, therefore, an image layer of 4 mm was selected. It can be programmed to acquire three sequential images of a region, the patient being moved 4 mm posteriorly between each image. However, the angular changes

TABLE 3 Percentages of Canals in Each Group (i.e., Central, Buccal, and Lingual) on the Tomograms and Sectioned Mandibles

		Tomogram	%	Direct	%	% Agreement	Correlation Coefficient	Sig.*
Orientation of inferior alveolar canal	Central	4	22.22	8	44.44	77.78	0.639	0.004
	Buccal	3	16.67	2	11.11			
	Lingual	11	61.11	8	44.44			

The table also shows the agreement percentages and Spearman's bivariate correlation coefficients between the findings on the tomograms and sectioned mandibles for the orientation of inferior alveolar canals.
*Correlation is significant at the 0.01 level (two-tailed).

(relative to the sagittal plane) within the patient's anatomy often prevent the acquisition of a total of three useful images.[3] Recently, Planmeca has introduced Promax machine with transtomography, which is a true linear tomography and provides cross-sectional images in both coronal and sagittal planes. The image layer thickness is selectable and the image layer width is uniform throughout the image.

The present study was limited only to the posterior region of the mandible because:[4] (1) premolar and molar regions of the mandible require knowledge of the location of the inferior alveolar canal vertically and bucco-lingually; (2) anterior looping of the inferior alveolar canal and other variations in the normal anatomy of the inferior alveolar canal must be anticipated; and (3) assessment of bone quality and morphology is needed to predict the success of the implant. These considerations make adequate presurgical implant imaging of paramount importance in this region.

Appropriate magnification factor was calculated for each tomogram in both vertical and horizontal directions. Tomograms showed non-uniform mean magnification in both horizontal and vertical planes. This can be the result of improper positioning of the mandible. However, this discrepancy between magnification factor given by the manufacturer (1.45) and the one calculated should be considered and the magnification factors for each site should be calculated separately to avoid any measurement error.

TABLE 4 Percentages for Appearance of Inferior Alveolar Canal in Each Group on the Tomogram

Non-quantitative Parameter	Classification	*N*	Percentage
Appearance of inferior alveolar canal	Good	3	16.67%
	Fair	3	16.67%
	Poor	8	44.44%
	Invisible	4	22.22%

TABLE 5 Intraexaminer Reproducibility and Interexaminer Variability for the Orientation of the Inferior Alveolar Canal on the Tomograms and the Sectioned Mandibles

		N	Agreement Percentage	Correlation Coefficient (*rs*)	Sig.*
Orientation of inferior alveolar canal	Tomogram	10	80	0.713	0.021
	Interexaminer	10			
	Tomogram	10	70	0.645	0.044
	Intraexaminer	10			
	Direct	10	80	0.667	0.035
	Interexaminer	10			
	Direct	10	80	0.745	0.013
	Intraexaminer	10			

The interexaminer and intraexaminer agreement percentages and the Spearman's bivariate correlation coefficients are also shown.
*Correlation is significant at the 0.05 level (two-tailed).

TABLE 6 Intraexaminer Reproducibility and Interexaminer Variability for the Appearance of the Inferior Alveolar Canal on the Tomograms

		N	Agreement Percentage	Correlation Coefficient (*rs*)	Sig.*
Appearance of inferior alveolar canal	Tomogram	10	80	0.918	0.000
	Interexaminer	10			
	Tomogram	10	80	0.877	0.001
	Intraexaminer	10			

The interexaminer and intraexaminer agreement percentages and the Spearman's bivariate correlation coefficients are also shown.
*Correlation is significant at the 0.01 level (two-tailed).

The total height and maximum bucco-lingual width were underestimated on the tomograms. The reason for the underestimation on the tomograms might be attributed to the possibility that the images of the mandibles without soft tissues burned out some thin anatomical structures (burn out effect), such as the crest of the mandible, thereby, making the exact identification not possible and causing error while tracing.[4] Underestimation of the total height on the tomogram was in agreement with the findings of Liang et al.[4] and Peltola and Mattila,[5] but was in disagreement with the findings of Potter et al.[3]

Distance between the inferior alveolar canal and the alveolar crest and distance between the buccal cortex and inferior alveolar canal were measured to evaluate the accuracy of this technique in locating the inferior alveolar canal in vertical and bucco-lingual direction. This is because in cases of severe resorption, the inferior alveolar canal may become completely unroofed and might lie along the superior edge of the mandibular body. An incision or reflection of the mucosa in this area could lead to the injury to these vital structures. Hence, knowledge of the position of the inferior dental canal in vertical as well as in bucco-lingual dimensions is of paramount importance during site preparation for implants.[10] These measurements were found to be overestimated. This could have been caused by error in tracing the canal outline as the visibility of the canal was poor in majority of cases (44.44%). Also, blurring of the tomographic image and errors in locating the tomographic image anatomically may have contributed to the measurement discrepancies.[11,12] Overestimation of the distance between the inferior alveolar canal and the alveolar crest was in agreement with the findings of

TABLE 7 Implant Dimensions Estimated Following the Protocol Described in the Proforma and the Measurements Done on the Radiographs (Tomograms, Panoramic Radiographs) and Mandibles (Intact and Sectioned Mandibles)

	Record 1		Record 2		Record 3	
Site No.	Diameter (mm)	Length (mm)	Diameter (mm)	Length (mm)	Diameter (mm)	Length (mm)
1	6.5	10	6.5	10	6.5	10
2	5.5	8	5.5	8	5.5	8
3	5.5	8	5.5	8	5.5	8
5	—	—	5.5	8	5.5	8
6	5.5	8	5.5	8	5.5	8
7	5.5	8	5.5	8	5.5	8
8	5.5	8	5.5	8	5.5	8
11	6.5	13	6.5	10	6.5	10
13	5.5	8	5.5	8	5.5	8
15	4.5	8	4.5	8	4.5	8
18	6.5	15	6.5	15	6.5	15

Potter et al.[3] who found that the tomogram overestimated the distance by 3.06% as compared with the 0.59% in our study. This disparity could have been due to the fact that they did not consider the magnification factor of each image. This finding was not in accordance with Peltola and Mattila[5] who found that the distance was underestimated. This could be explained on the basis that the study was conducted on a different machine.

The cortical thickness at the inferior border of the mandible was measured to assess the accuracy of panoramic tomograms in measuring the small distances, and it was found that they were overestimated. The overestimation could be due to the fact that the inferior border of the mandible was situated horizontally, while the central ray of the unit is not horizontal.[5] This was in accordance with the study by Peltola and Mattila[5] but was not in accordance with Potter et al.[3]

Despite these differences between the measurements done on the tomograms and gold standards, 95% of them were within the range of ±1 mm (95% confidence interval of the difference) which are within the acceptable range for implant treatment planning. Also, these differences were of little significance as none of them were found to be statistically significant. Interexaminer reproducibility and intraexaminer variability for these measurements were also statistically not significant.

Another most important aspect is the appearance of the inferior alveolar canal. The appearance was poor (i.e., canal was identifiable but without any cortication) in majority of cases on the tomogram. Various explanations had been given for this:[4,8] (1) the mandibular neurovascular bundle is not always surrounded by an ossified canal[13]; (2) the cortical margins surrounding the inferior alveolar nerve might have "burned out"; and (3) the resolution of the tomograms might be insufficient to clearly resolve the cortication. But the most probable explanation seems to be that the appearance of cortication of the inferior alveolar canal on the radiograph depends upon the geometry of the radiographic projection used, the proximity of the canal to the cortical bone in the projected plane, and the variation in radiodensity (compactness and thickness) of the closely apposed anatomic structures. If the mandibular nerve is closely apposed to the buccal or lingual cortical plate and if the x-ray beam is directed perpendicular to the inferior alveolar neurovascular bundle, a smooth radiodense delineation or cortication is produced on the film at the margin of the canal. However, in cross-sectional tomography the radiolucent canal and the radiodense cortical plate are parallel in the projected geometric plane and thus the radiographic visualization of the corticated margin is less apparent on this view.[4]

The bucco-lingual orientation of inferior alveolar canal is also an important parameter to be considered while placing the implant as this will minimize the chances of accidental damage to the inferior alveolar canal. The findings on the tomograms showed a good agreement percentage and a good correlation with the gold standards. However, this parameter has not been evaluated yet using panoramic cross-sectional tomography.

The interexaminer reproducibility and intraexaminer variation for the appearance and orientation of the inferior alveolar canal showed a good percentage agreement and a good correlation.

Based on the above-mentioned measurements and observations, implant sizes were estimated for the 11 proposed implant sites. There was a change in the estimated implant size at two sites (5 and 11) between record 1 and record 2. However, there was no disagreement in the size of the implant estimated from record 2 and 3 by both the observers. So, it can be concluded that the panoramic cross-sectional tomography can be reliably used for the implant size estimation. Recently, Frei et al.[7] in their study on the necessity for cross-sectional imaging of the posterior mandible in implant treatment planning concluded that cross-sectional imaging did not have any major impact on the implant size estimation in mandibular posterior region. Vazquez et al.[14] also in their study concluded that cross-sectional imaging techniques may not be necessary for preoperative evaluation for implant placement. Panoramic examination can be considered as a safe, quick, simple, low-cost, and low-dose presurgical diagnostic tool for preoperative implant treatment planning in mandibular posterior region, keeping a safety margin of at least 2 mm above the inferior alveolar canal. Even though in our study also, the tomograms did not have a major impact on implant size estimation (change in implant size only at two sites), but they could be useful in providing vital information regarding the location of the anatomic structures in vertical and horizontal planes, morphology of the alveolar bone, and the quality of the alveolar bone. These are important parameters for implant treatment planning and can only be provided by cross-sectional imaging. Also, when greater accuracy is required, measurements on orthopantomogram are not recommended.[15] In such cases, measurements on tomographic images are recommended, especially in mandibular posterior region, as these images not only show bucco-lingual orientation of the inferior alveolar canal, but also show greater accuracy of measurements than orthopantomogram.[16] Bolin et al. also concluded that for estimating available bone for implant in mandibular posterior region, tomograms were better than orthopantomograms.[17]

The last but not the least is the amount of radiation exposure. Kassebaum et al.[18] found that an examination of individual implant sites with the linear tomographic technique delivered a much smaller dose to anatomic sites than either a maxillary or a mandibular CT scan did. The linear tomographic technique delivered a smaller dose to the selected anatomic sites when multiple implant sites in the mandible were examined. However, when the doses delivered from a CT scan of the maxilla were compared with doses delivered during multiple tomographic cuts of the entire maxillary arch, the dose from the CT scan was smaller. Lecomber et al.[19] found that the organ absorbed doses for panoramic, cephalometric, and cross-sectional tomography using dental panoramic radiography (PM2002 CC Proline) were 0.004 mSv, 0.002 mSv, and 0.002 mSv, respectively, whereas with CT it was 0.314 mSv and concluded that the CT techniques can provide excellent images, but at the cost of increased radiation detriment. So, the panoramic cross-sectional tomography may give adequate clinical information at a greatly reduced dose.

To summarize, the tomograms were found to be accurate for the measurements in both horizontal and vertical planes and reliable for implant size estimation at a greatly reduced dose, taking into consideration proper magnification factors. They were also found to be useful in assessing the orientation of inferior alveolar canal but were not very effective in discerning it.

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APPENDIX: PROTOCOL FOR ESTIMATING IMPLANT DIMENSIONS

Estimation of Implant Diameter

The diameter of the implant is estimated by calculating the available bone length and available bone width.

- *Available bone length:*
  - ■ It is the mesio-distal dimension of the edentulous region.
  - ■ Measure this distance on the panoramic radiographs and on intact mandibles.
  - ■ 3 mm of bone is optimal between each implant and 2 mm between implant and natural tooth.
    - – *In case of single implant placement:*

      Implant Diameter = Actual M-D length – 4 mm (2 mm on either side of Implant site)
    - – *In case of more than one Implant:*

$$\text{Implant Diameter} = \frac{\text{Actual M-D length} - 3\text{ mm between two implants} - 4\text{ mm (2 mm on either side of implant site)}}{\text{Number of implants}}$$

- *Available bone width:*
  - – Bucco-lingual width available for placement of implant.
  - – The inserted implant should be invested by 1 mm of bone both buccally and lingually.
  - – Measure this distance on the tomograms, intact mandibles, and on sectioned mandibles.
  - – Implant Diameter = Bucco-lingual width – minimum of 2 mm.

Estimation of Implant Length

The implant length is estimated by calculating the available bone depth.

- *Available bone depth:*
  - – Bone depth is the distance from crest to the superior border of the inferior alveolar canal.
  - – Measure this distance on the panoramic radiographs, tomograms, and on sectioned mandibles.
  - – Also measure the amount of bone to be removed from the crest to place the implant of estimated diameter.
  - – Implant Length = Distance from crest to the superior border of the inferior alveolar canal – amount of bone to be removed to place the implant of estimated diameter – 1 mm superior to the inferior alveolar canal roof as safety margin.