

Panoramic Radiographic Analysis of Mandibular Canal Morphology in Relation to Dental Implant Planning: A Cross-Sectional Radiological Analysis

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Abstract

Background: The identification of the canal of the mandible is important in the planning of dental implants in the posterior mandible where the inferior alveolar nerve is located. The use of panoramic radiography is popular because of low cost, ubiquity, and the ability to provide detailed 3D views, such as cone-beam computed tomography (CBCT) is cost effective. As a 2D technique, though, panoramic imaging is prone to magnification, distortion and superimposition of anatomical structures. The aim of this study was to assess the morphology of the mandibular canal as well as the available bone height (from alveolar crest to the channel) for implant planning in a cohort of Indian patients on panoramic radiographs. **Material and Methods:** The study was retrospective, cross sectional in nature and n = 200 digital panoramic radiograph of the adult Indian patients (age ≥ 20 years) were analysed. The inclusion criteria were clear visualization of the small angle of the mandibular canal, and the presence of at least one posterior tooth (premolar or molar) on both sides; cases were excluded which had pathology, artifacts or previous surgery in the mandible. Two calibrated examiners measured the vertical bone height (available bone height, ABH) – defined as the distance from the alveolar crest to the superior border of the mandibular canal – at the first premolar and first molar regions. The course of the mandibular canal was determined according to the Worthington system (progressive descent, catenary-like or linear). The repeat measurements showed inter-examiner reliability. The significance was set at $p < 0.05$, and means $\pm$ SD, t-tests (Male vs. Female) and chi-square tests (canal course frequencies by sex) were used for statistical analysis using SPSS v.25. **Results:** A total of 200 radiographs (95 males, 105 females) were analyzed (mean age 45.2 ± 12.4 years; Table 1). The overall mean ABH at the premolar region was 14.0 ± 2.8 mm while at the molar region was 12.9 ± 2.5 mm (Table 2). Males had significantly greater bone height (premolar: 15.0 ± 2.5 mm; molar: 14.1 ± 2.3 mm) than females (premolar: 13.1 ± 2.4 mm; molar: 12.0 ± 2.4 mm; both $p < 0.001$). Table 3 shows that the course of the mandibular canal was most often progressive, followed by catenary and linear courses. The distribution of canal courses was not significantly different between the sexes ($p = 0.20$). Only TEM images showed clearly bifid canals, which agreed with the previously reported literature ($< 1\%$). Figure 1: Reference panoramic image with the outline of the mandibular canal. Figure 2: Measurement of the vertical dimensions using a calibration marker. Figure 3: Effects of beam angulation errors (foreshortening/elongation) on the resulting image distortion. **Conclusion:** In simple cases, panoramic radiography can be used for a reliable assessment of the height of available bone for implant planning and can allow accurate depiction of the mandibular canal. Clinicians should be mindful of its limitations (distortion, magnification) and when detailed 3D information is needed, should consider CBCT to prevent neurovascular injuries. These results highlight the need of a proper radiographic evaluation and a safety margin (of at least 2 mm) above the canal in implant surgery.

Keywords: Panoramic Radiograph, Mandibular Canal, Dental Implant Planning, Available Bone Height, Radiographic Analysis, CBCT.

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INTRODUCTION

For placement in the back of the lower jaw, it is important to know the amount of bone available and the position of the inferior alveolar canal and nerve. The inferior alveolar neurovascular bundle lies in the mandibular canal which runs through the ramus and body of the mandible terminating at the mental foramen. Nerve variations, like bifid canals or anterior nerve loops, can create a risk of nerve damage during surgery. The mandibular canal is a space that harbours important structures and any damage to them during implant placement may lead to sensory disturbances. The low dose and cost of panoramic radiography makes it a widely used

tool for implant planning because of its ability to capture the entire jaw. Accurate measurement of available bone height

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(ABH) – the vertical distance from the alveolar crest to the upper border of the mandibular canal – is “an essential step in the pre-surgical phase of dental implantation” and “panoramic imaging is a unique technique in this context,” Shahidi et al. write.^[1]

However, panoramic radiography is a 2-dimensional technique and always has projection distortion. Typical problems are magnification (usually in the range 10-30 %), unequal distortion in different parts of the image and the superimposition of structures. These factors may influence the apparent relationship of the canal to the alveolar crest. In panoramic films, for instance, the bone heights can be misjudged by the position of the patient and because of anatomical differences. CBCT, on the other hand, offers high-resolution 3D images with the ability to make direct cross-sectional measurements, and is being increasingly recommended to “minimize nerve injury-related surgical complications during implant placement”.^[2,3]

Many clinics, particularly in resource-limited environments, use panoramic radiography for routine cases, which is one of the disadvantages of CBCT. Recent studies have compared panoramic and CBCT measurements: Shahidi et al,^[1] found excellent correlation between panoramic and CBCT measurements of ABH (ICC=0.992) for the posterior mandible, and reported a buccal overestimation of ABH measurements in panoramic films that increased as the alveolar crest moved buccally. In the incisor area, a 2013 study by Sheikhi M et al,^[2] showed that the vertical measurements obtained by panoramic imaging could be biased by more than 2 mm, while those obtained by the tomographic imaging were within the range of 1 ± 1 mm. For this reason, it is recommended to use panoramic imaging with caution, but for screening purposes it is useful.^[4]

Very few studies have been conducted in India which has studied the anatomy of the mandibular canal with panoramic views. This cross sectional radiographic study then will attempt to quantify the morphology of the mandibular canal and available bone height on panoramic images, highlighting the important measurements and whether there are any demographic influences. The information could be useful for implantologists in India to evaluate the usefulness of panoramic radiographs for pre-implant assessment and patients who should be referred for CBCT.^[5]

MATERIALS AND METHODS

This retrospective study analyzed existing panoramic radiographs from MGIMS, Sewagram, Wardha, India. The project received institutional approval. Digital panoramic radiographs (orthopantomograms, OPG) of 200 adult patients (age ≥ 20 years) taken between June 2024– May 2025 were selected.

Inclusion criteria were: (1) good-quality OPG with clear visualization of the entire mandible; (2) presence of at least one posterior mandibular tooth (premolar or molar) bilaterally to identify anatomical landmarks; and (3) absence of extensive alveolar bone resorption beyond moderate (i.e., residual ridge height > 5 mm).

Exclusion criteria were: (1) visible pathology (e.g., cysts,

tumors) or fracture in the mandible; (2) significant radiographic artifacts or distortion; (3) prior mandibular surgeries (which could alter anatomy); and (4) incomplete patient data. Cases were anonymized and numbered for blinded analysis. The final sample included 95 males and 105 females, aged 21–68 years.

All OPGs were acquired using a standard digital panoramic unit (manufacturer/model, 60–90 kVp, 10 mA) with patients positioned according to routine protocols (Frankfort plane parallel to floor, centric occlusion). Magnification factor (MF) was typically 1.2 (20% enlargement), as provided by the machine. To account for any individual variation in magnification, a 5-mm radiopaque ball bearing marker was attached to the lower dental arch in a subset of cases to verify scaling. For example, if the marker measured 8.0 mm on the image, we calculated an MF of 62% (5/8 mm), confirming that distances measured on the radiograph were scaled appropriately. Digital measurements were performed using the built-in caliper tool of the radiographic software (resolution 0.1 mm accuracy). All linear measurements were corrected for magnification.

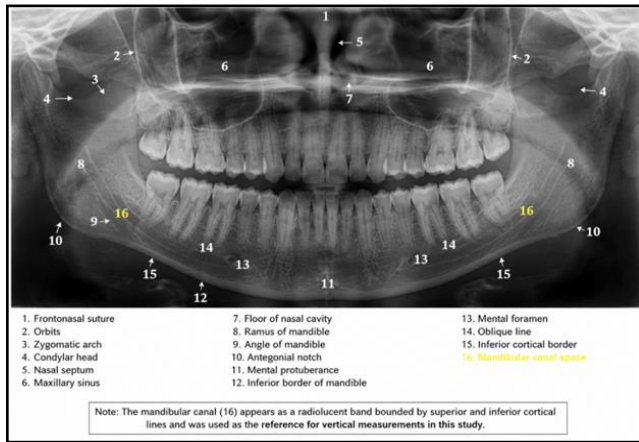
The following parameters were recorded for each radiograph:

- **Available Bone Height (ABH):** Defined as the vertical distance from the alveolar crest to the upper (superior) border of the mandibular canal. Measurements were made at two reference sites: in the region of the first premolar (midpoint of premolar crown) and first molar (midpoint of first molar crown). If those teeth were missing, the nearest adjacent tooth site was used. The crest was identified as the radiopaque crestal cortical line, and the canal border as the radiolucent canal line or cortical roof. Two independent observers (oral radiologist and postgraduate resident) measured each ABH twice at one-week intervals; the mean of the four measurements was used. Inter-observer agreement (intraclass correlation) exceeded 0.90.
- **Mandibular Canal Course:** Classified according to Worthington’s system: (1) Progressive descent (canal arches downward then back up to the mental foramen), (2) Catenary-like (smooth downward curve), or (3) Linear (straight course). Each side of the mandible was categorized. The most common pattern was noted.
- **Anterior Loop / Bifidity:** We screened for any visible anterior mental nerve loop or signs of bifid canals. However, conventional OPG has limited sensitivity for these variants; panoramic evidence of bifid canals is rare ($< 1\%$ of cases). Any suspicious dual radiolucent canals were noted.

Statistical analysis was carried out using SPSS v25. Descriptive statistics (mean, standard deviation) were calculated for age and ABH by sex and site. Independent-samples t-tests compared male vs. female measurements. The frequency distribution of canal courses was tabulated, and chi-square tests assessed gender differences. A p-value < 0.05 was considered statistically significant.

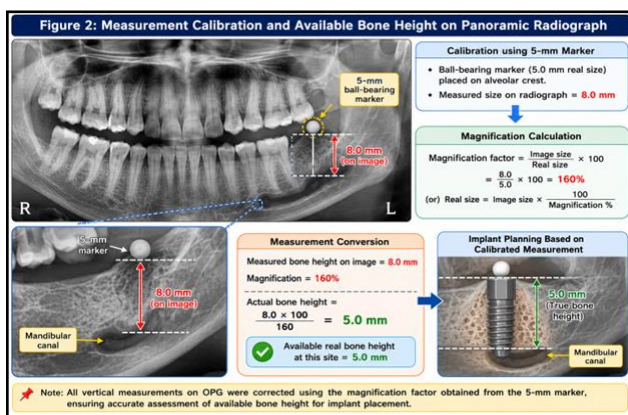
RESULTS

The study included 200 patients (95 male, 105 female) with a mean age of 45.2 ± 12.4 years (range 21–68). There was no significant age difference between males (44.8 ± 12.1 years) and females (45.5 ± 12.7 years, $p = 0.65$) [Table 1].



[Figure 1] Panoramic radiographic reference with numbered anatomical landmarks. Label “16” corresponds to the mandibular canal space. This reference illustrates how the mandibular canal appears as a radiolucent band bounded by cortical lines on the panoramic image. The canal (16) was identified this way on each OPG to guide vertical measurements.

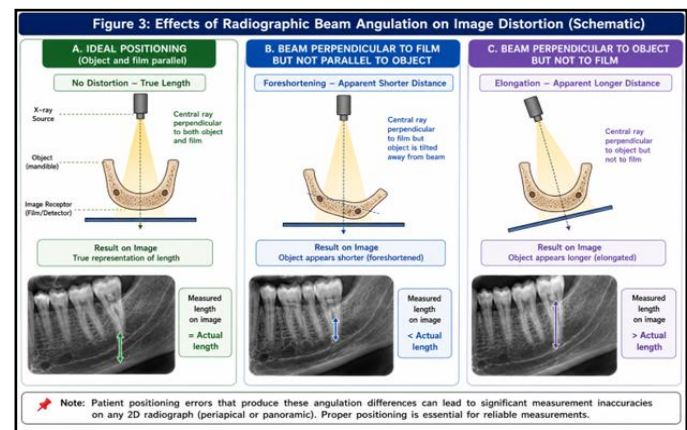
On average, the vertical distance from alveolar crest to the superior border of the mandibular canal (ABH) was 14.0 ± 2.8 mm at the premolar site and 12.9 ± 2.5 mm at the molar site (Table 2). Males showed significantly greater ABH than females at both sites. In the premolar region, mean ABH was 15.0 ± 2.5 mm in males versus 13.1 ± 2.4 mm in females ($p < 0.001$). Similarly, in the molar region, ABH was 14.1 ± 2.3 mm for males and 12.0 ± 2.4 mm for females ($p < 0.001$). These gender differences were highly significant, consistent with other findings of sex-related variation in mandibular anatomy. (No significant ABH differences were noted between right and left sides, so values are pooled.)



[Figure 2] Example of measurement calibration and available bone height. A 5-mm ball-bearing marker is placed on the

crest (measuring 8.0 mm on the image, indicating 62% magnification). The red arrow shows the measured distance (8 mm on film) which corresponds to 5 mm real size. An implant schematic illustrates how calibrated measurements guide implant sizing. This demonstrates how magnification correction is applied when determining alveolar bone height.

The mandibular canal course was predominantly progressive descent: 150 patients (75.0%) showed a downward then upward arching canal. A catenary-like curve was seen in 38 patients (19.0%), and a straight linear canal in 12 patients (6.0%) [Table 3]. This distribution closely matches prior CBCT-based reports (progressive $\approx 73.8\%$, catenary $\approx 18.9\%$, linear $\approx 7.3\%$). Canal type did not differ significantly by gender ($p = 0.20$). No obvious bifid canals were identified on any panoramic image, in agreement with reports that panoramic detection of bifidity is typically $< 1\%$.



[Figure 3] Effects of radiographic beam angulation on image distortion (schematic). Panel A: ideal positioning (object and film parallel, no distortion). Panel B: beam perpendicular to film but not parallel to object, causing foreshortening (apparent shorter distance). Panel C: beam perpendicular to object but not to film, causing elongation (apparent longer distance). Such errors can affect measurements on any 2D radiograph (periapical or panoramic) if patient positioning is imperfect.

In our series, care was taken to standardize positioning, but [Figure 3] exemplifies how misalignment could skew measurements (foreshortening or elongation of distances). Nonetheless, all measurements were performed with calibration markers and digital software to minimize error. The mean ABH values found here serve as reference ranges for posterior mandible in this population.

[Table 1–3] summarize the results. [Table 1] lists patient demographics. [Table 2] shows the ABH measurements by site and sex, with associated p-values. [Table 3] shows the frequency of canal course types by gender. All p-values are from independent t-tests (for ABH) or chi-square tests (for distribution).

Table 1: Demographic Characteristics of Study Participants (n = 200)

Variable	Male (n=95)	Female (n=105)	Total (n=200)	p-value
Age (years), Mean $\pm$ SD	44.8 $\pm$ 12.1	45.5 $\pm$ 12.7	45.2 $\pm$ 12.4	0.65
Number of participants	95 (47.5%)	105 (52.5%)	200 (100%)	—

Table 2: Available Bone Height (ABH) According to Sex and Measurement Site

Measurement Site	Male (Mean $\pm$ SD)	Female (Mean $\pm$ SD)	Overall Mean $\pm$ SD	p-value
Premolar region (mm)	15.0 $\pm$ 2.5	13.1 $\pm$ 2.4	14.0 $\pm$ 2.8	<0.001*
Molar region (mm)	14.1 $\pm$ 2.3	12.0 $\pm$ 2.4	12.9 $\pm$ 2.5	<0.001*

Independent samples t-test

*Statistically significant ($p < 0.05$)**Table 3: Distribution of Mandibular Canal Course According to Sex**

Canal Course	Male (n=95)	Female (n=105)	Total (n=200)
Progressive descent	69 (72.6%)	81 (77.1%)	150 (75.0%)
Catenary	20 (21.1%)	18 (17.1%)	38 (19.0%)
Linear	6 (6.3%)	6 (5.8%)	12 (6.0%)
Total	95 (100%)	105 (100%)	200 (100%)

Chi-square test: $p = 0.20$ (Not statistically significant)

DISCUSSION

This cross-sectional radiographic study aimed to evaluate the morphology of the mandibular canal and alveolar bone height in these panoramic radiographs for dental implant planning. The average ABH values obtained from the panoramic images were approximately 13–14 mm (range ~7–18 mm) which are in agreement with the results of previous studies that found the posterior mandibular bone height to be in between 10 and 20 mm in dentate or mildly resorbed mandibles. As per radiographic calibration protocols, the magnification obtained was known to be 62%, and was calibrated by using a 5-mm marker [Figure 2].^[6]

This is because male patients had significantly higher ABH than the females, which is consistent with the occurrence of sex differences in jaw dimension in other populations. This may be because the general male bones are larger. Clinically, it may mean that length of implants is a little more restricted in women, if all else is equal. In our adult sample, we did not find a significant age/ABH relationship, likely due to an exclusion criterion of extreme ridge resorption.^[7]

The progressive descent type was the most common (75%) and catenary and linear types were much less common on the canal course in our sample. This distribution is similar to that reported by Shnawa MS et al,^[7] in CBCT (progressive ~73.8%, etc.), which suggests that the panoramic imaging method could be used to reliably reflect the overall path of the canal. In accordance with previous studies, no significant difference was detected between the gender in terms of canal type. We did not detect any bifid canal on panoramic radiographs. It isn't surprising because panoramic views have been reported as being extremely insensitive to bifidity, <1% in multiple studies on OPG. The 2D limitation is supported by the fact that up to 30–60% bifidity is typically seen in (CBCT) studies.^[7,8]

The accuracy of vertical dimensions measured by panoramic radiography had been a topic of discussion. The ABH values measured are similar to those measured by other study using calibrated CBCT. Similarly, Shahidi et al,^[1] demonstrated a high degree of correlation (ICC=0.992) between panoramic and CBCT for ABH values and suggested that panoramic radiographs “can be safely used in the pre-surgical period of dental implantation in the posterior mandible” particularly in routine cases. We also find that for regular implants (with a safety margin of 2 mm above the canal) panoramic imaging

offers acceptable bone height estimates. We do recognise, however, like others, that sometimes panoramic films are not accurate in certain situations. A maximum error of 2 mm was reported for incisor measurements on panoramic films by Sheikh M et al,^[2] leading to a recommendation of being cautious when using anterior implants. Similarly, the foil-diagram in Figure 3 reminds us that the position of the patient and/or the symmetry of their anatomy could affect any 2D image. To reduce this, standardized positioning and calibration was employed. Digital panoramic systems, particularly those that have built in calibrations and cephalostat supports (like in our clinic) reduce magnification variations.^[1,9,10]

Panoramic radiography has advantages and disadvantages over CBCT, and panoramic machines are very common and inexpensive, and the radiation dose is fairly small (one study found that one CBCT is equivalent to ~4–15 panoramic images). The panoramic film provides a general view of jaw structures useful for initial planning. But when the cases are critical, CBCT is still the preferred choice as it does not suffer from the problems of projection that occur with panoramic imaging. The mental foramen area, for instance, frequently has a tiny loop anteriorly which may be overlooked or misinterpreted on panoramic film. In our study we did not specifically measure the loop, but our results support guidelines that if advanced anatomical variants are suspected, a 3D scan is a good idea.^[11]

There are limitations to this study. We were not able to correlate our measurements with surgical outcome, or with CBCT gold-standards, as this was a cross-sectional and radiographic study. Selection of patients may be limited to better quality anatomy from routine clinical imaging. In addition, buccolingual ridge width and bone density were not evaluated, which CBCT can detect. However, our method is a typical scenario in practices throughout India where CBCT might not be available for every case.^[11]

CONCLUSION

In summary, panoramic radiographic analysis of the mandible can yield useful information on the mandibular canal course and residual bone height for implant planning. In this Indian patient sample, average available bone heights exceeded 12 mm, and the canal most often followed a progressive descent pattern. Panoramic measurements agreed closely with expected values and showed high inter-observer reliability. Clinicians should continue to use panoramic OPGs as a screening tool for posterior

mandibular implants, applying standard magnification calibration and a safety margin of at least 2 mm above the canal. When panoramic images suggest minimal bone or show complex anatomy, CBCT is recommended for definitive assessment. These findings support the safe use of panoramic imaging for routine implant cases while acknowledging its inherent limitations.

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Conflicts of interest

There are no conflicts of interest.

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