World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Quantifying vertical and oblique distortions in panoramic radiography: A comparative analysis of dry mandible measurements

Rini Widyaningrum [1, 2, *], Rellyca Sola Gracea [2], Munakhir Mudjosemedi [2], Eha Renwi Astuti [1], Adioro Soetojo [3] and Aga Satria Nurrachman [1]

[1] Oral and Maxillofacial Radiology Specialist Study Program, Faculty of Dental Medicine, Universitas Airlangga, Jl. Mayjen Prof. Dr. Moestopo No.47, Surabaya, Indonesia. 60132.
[2] Department of Dentomaxillofacial Radiology, Faculty of Dentistry, Universitas Gadjah Mada, Jl. Denta No.1, Sekip Utara, Yogyakarta, Indonesia. 55281.
[3] Department of Conservative Dentistry, Faculty of Dental Medicine, Universitas Airlangga, Jl. Mayjen Prof. Dr. Moestopo No.47, Surabaya, Indonesia. 60132.

World Journal of Advanced Research and Reviews, 2025, 27(01), 705-712

Publication history: Received on 29 May 2025; revised on 02 July 2025; accepted on 05 July 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.27.1.2572

Abstract

Panoramic radiography provides significant diagnostic advantages by capturing the maxilla and mandible in a single projection, offering a rapid and low-radiation imaging solution. However, inherent limitations such as magnification and geometric distortions may compromise measurement accuracy. This study quantitatively evaluates discrepancies in vertical and oblique measurements between dry mandible specimens and panoramic radiographs. Fifty-six dry human mandibles were marked with 23 metal reference points at key anatomical landmarks. Direct physical measurements were obtained using a digital sliding caliper, while radiographic measurements were derived from digital panoramic images with specialized software. Statistical analysis revealed significant differences ($p < 0.05$) in vertical and oblique dimensions, except in the anterior mandible. Posterior regions exhibited pronounced magnification, with vertical distortions ranging from 10% to 18% and oblique distortions from 9% to 22%. In contrast, anterior regions demonstrated minimal distortion (vertical: 6%–9%; oblique: 1%–3%). The greatest vertical magnification occurred at the mandibular ramus, while the largest oblique distortion was observed in measurements spanning the inter-incisal alveolar crest to the coronoid process. These findings indicate that panoramic radiographs provide reliable accuracy for anterior mandibular assessments but exhibit clinically relevant inaccuracies in posterior measurements, particularly in vertical and oblique orientations. This study highlights the need for caution when interpreting vertical and oblique dimensions of the posterior mandible in panoramic imaging for diagnostic or treatment-planning purposes.

Keywords: Radiograph; Panoramic; Measurement; Mandible; Distortion

1. Introduction

The field of radiography has undergone significant advancements in medical applications since Wilhelm Röntgen discovered X-rays in 1895. Dental radiography was first performed in 1896 and has since become an indispensable diagnostic tool in dental practice.[1,2] Currently, dental radiographs represent the most widely utilized diagnostic modality in clinical dentistry, with radiographic equipment becoming increasingly accessible across healthcare facilities.[3] The growing demand for diagnostic imaging in dental practice has driven continuous innovations in radiographic technology. While conventional film served as the primary imaging medium during the early development

* Corresponding author: Rini Widyaningrum

of radiographic imaging, it has been progressively replaced by digital display systems, including monitors and printed media, marking the transition to digital radiography as the current standard in imaging technology.[1,4]

The need for more precise imaging technology has expanded radiographic examination beyond conventional two-dimensional imaging to include intraoral, panoramic, and various skull projections. Clinical applications increasingly require multiplanar imaging systems capable of visualizing anatomical structures with greater detail, down to centimeter,[2] or even sub-millimeter[5] resolution. Advanced imaging modalities such as computed tomography (CT) and magnetic resonance imaging (MRI) provide detailed visualization of anatomical structures while overcoming the superimposition artifacts inherent in conventional two-dimensional imaging. Despite their advantages over traditional radiographs, these advanced imaging technologies[6] significantly increase healthcare costs. Furthermore, their availability remains limited primarily to urban centers.[7] Consequently, conventional two-dimensional imaging systems remain the most widely used diagnostic tools, particularly in developing countries.

Orthopantomography (OPG), commonly referred to as panoramic radiography, is a widely used radiographic technique for treatment planning and diagnostic purposes in dental practice. Panoramic radiographs provide comprehensive visualization of facial structures, including the maxilla, mandible, and temporomandibular joints (TMJ) in a single image.[8] This imaging modality is acquired through simultaneous movement of the X-ray source and image receptor (either film or digital sensor) in opposite directions around the patient's head.[9]

Panoramic radiography serves as an important screening tool before prosthodontic treatment, enabling detection of retained roots, intraosseous cysts, foreign bodies, or neoplasms.[10] Vertical and oblique measurements obtained from panoramic radiographs are particularly valuable for treatment planning and post-treatment evaluation of jaw tumors, fractures, TMJ disorders, and developmental anomalies such as mandibular hyperplasia or hypoplasia. The technique offers several advantages for maxillomandibular screening,[7] including relatively low cost and reduced radiation exposure compared to advanced imaging modalities like CT.[11] These benefits have established panoramic radiography as the most commonly used extraoral imaging technique in dental practice, with its utilization continuing to grow.[12,13] However, panoramic radiographs are subject to limitations including image magnification and geometric distortion relative to actual anatomical dimensions, necessitating careful interpretation to prevent diagnostic errors.[7,14] Additional limitations include reduced contrast resolution, limited detail recognition, and inability to provide cross-sectional views. The technique is also prone to superimposition artifacts involving the maxilla, mandible, and adjacent maxillofacial structures such as cervical vertebrae, the hyoid bone, and the hard palate.[15]

Dental practitioners have utilized panoramic radiography for over fifty years,[15] with applications including screening examinations, periodontal evaluation, orthodontic treatment planning, oral surgery procedures, and dental implant assessment.[15] Accurate jawbone dimensional analysis is particularly crucial for diagnosis and treatment planning in implant dentistry, impacted teeth management, tumor and cyst evaluation, and temporomandibular joint disorders (TMDs). Despite its limitations, panoramic radiography remains widely used in clinical practice. The technique is constrained by its narrow focal trough, with structures outside this zone appearing blurred or distorted. Furthermore, soft tissue and air shadow artifacts may create radiolucent areas that obscure underlying hard tissue structures[16]. As noted by Pittayapat et al. (2012),[17] panoramic radiography exhibits significant limitations related to geometric distortion and anatomical superimposition. The degree of distortion varies depending on the specific X-ray equipment and measurement parameters, typically ranging from 0.7 to 1.8 times the actual anatomical dimensions.[4,16]

Nevertheless, panoramic radiography remains valuable for obtaining mesiodistal views of dental structures. The present study aims to quantify panoramic radiographic distortion by comparing vertical and oblique measurements between dry mandible specimens and their corresponding radiographic images. The findings are expected to provide clinically relevant data regarding measurement inaccuracies in panoramic radiography. These results may assist clinicians in treatment planning and postoperative evaluation of jaw tumors, fractures, and developmental anomalies, as well as in the assessment of TMJ-related conditions.

2. Material and methods

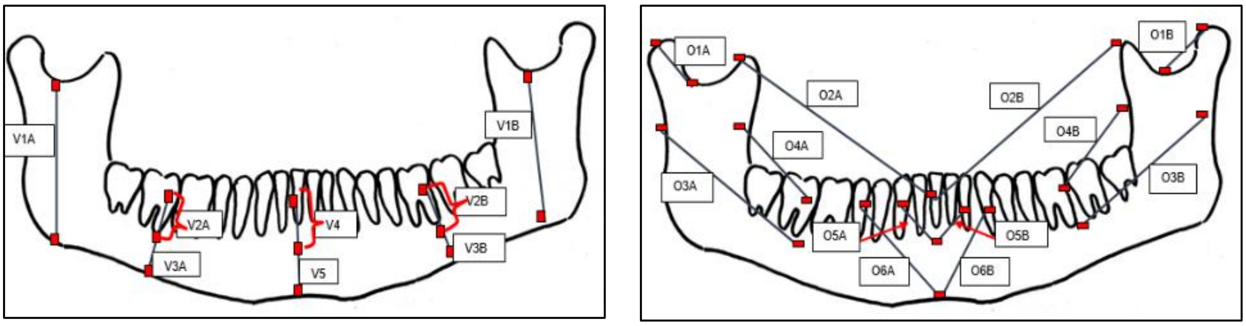
Ethical approval for this study was obtained from the Ethics and Advocacy Unit of the Faculty of Dentistry, Universitas Gadjah Mada, Yogyakarta, Indonesia. This experimental study involved radiographic imaging of 56 dry mandible specimens using panoramic X-ray equipment. The specimens were sourced from the Department of Anatomy, Embryology, and Anthropology at the Faculty of Medicine, Universitas Gadjah Mada. Inclusion criteria required complete anatomical structures including the condyle, coronoid process, ramus, mandibular angle, and mandibular body, with or without teeth present.

Before panoramic radiographic examination, each mandible was marked with 23 metal reference points at predetermined anatomical locations (Figure 2). The markers were fabricated from 0.4 mm-thick copper (Cu) sheets, cut into 2 mm × 2 mm squares. These fiducial markers ensured consistent landmark identification between direct physical measurements and radiographic measurements.

Panoramic radiographs were acquired using a Yoshida Panoura Deluxe X-ray unit (Japan) with exposure parameters of 55-60 kVp, 6 mA, and 12-second exposure time. Specimens were positioned on the chin rest using custom fixation devices to simulate clinical positioning, with particular attention to reproducing the mandibular orientation observed in live patients. The mentum was positioned on the chin rest while maintaining the gonion at a higher position, resulting in mandibular rami perpendicular to the horizontal plane and the occlusal plane angled 20°-30° below the horizontal axis. The mandibular midline was carefully aligned with the center of the chin rest to ensure symmetrical imaging.

Figure 1 Panoramic radiography of the dry mandible

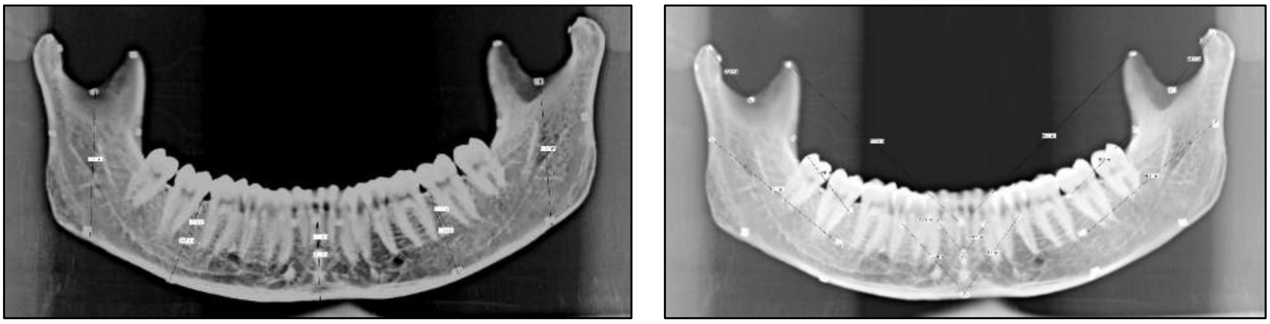
The resulting images were captured using a VistaScan scanner and processed with DBSWIN 4.5 software (Dürr Dental, Germany). Figure 1 demonstrates a representative panoramic radiograph of a dry mandible specimen. Rigorous quality assurance protocols were implemented to verify that all radiographs met clinical standards, with particular attention to proper occlusal plane curvature (slightly concave without inversion) and complete visualization of all mandibular structures.



A B

Figure 2 Metal marker position and imaginary line of vertical (A) and oblique (B) measurements

Vertical measurements were obtained along eight predetermined lines (V1-V5, Figures 2A and 3A), while oblique measurements were taken along ten lines (O1A-O6B, Figures 2B and 3B). Measurement locations were selected to represent clinically relevant regions including: the dental alveolar process, anterior mandibular body (V4, V5, O5, O6), posterior mandibular body (V2, V3), mandibular rami (V1, O3, O4), and condyles (O1). The O2 measurements specifically assessed distortion patterns from the midline to posterior regions.



A B

Figure 3 Vertical (A) and oblique (B) measurements on digital panoramic radiographs

Direct physical measurements were obtained using a digital sliding caliper (Krisbow®) with 0.01 mm resolution. Corresponding radiographic measurements were performed using DBSWin 4.5 digital radiography software on calibrated computer workstations.

3. Results and discussion

3.1. Vertical Measurement

The results of vertical measurements are presented in Table 1, while oblique measurements are shown in Table 2. Analysis of vertical measurements (Table 1) revealed statistically significant differences ($p < 0.05$) between panoramic radiographs and direct dry mandible measurements for all regions except the V4 measurement ($p > 0.05$). The vertical ramus (V1A and V1B) and posterior mandibular regions (V2A and V2B) demonstrated greater distortion compared to the anterior mandibular regions (V4 and V5).

The non-significant difference observed in V4 measurements ($p > 0.05$) suggests superior measurement accuracy in the anterior mandible, particularly for shorter measurement distances. This finding is supported by the minimal distortion ratio (1.07) shown in column (10) of Table 1, representing the smallest distortion among all vertical measurements.

Table 1 Data and the result of the comparison test on vertical measurement

Measurements	Measurements on dry mandibles (A)				Measurements on Panoramic Radiographs (B)				Mean of OPG Distortion (B/A)	p
	Mean	SD	Min	Max	Mean	SD	Min	Max		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
V1A	44.34	5.28	29.30	58.77	51.34	6.32	35.00	69.70	1.16	0.000^{*T}
V1B	43.04	6.77	22.30	59.97	50.95	5.94	37.50	69.50	1.21	0.000^{*T}
V2A	12.70	2.44	7.96	18.00	13.99	2.82	7.80	19.60	1.10	0.011^{*T}
V2B	12.69	2.11	7.79	15.94	13.98	2.61	8.60	18.20	1.10	0.02^{*M}
V3A	22.16	4.81	11.34	30.86	25.57	5.40	12.70	35.90	1.16	0.001^{*T}
V3B	22.38	4.25	11.94	29.97	25.76	5.21	13.30	34.90	1.15	0.000^{*M}
V4	12.91	2.51	8.07	18.34	13.74	2.58	9.00	21.00	1.07	0.090^{T}
V5	23.44	4.71	15.05	33.65	25.60	4.94	16.90	37.70	1.09	0.020^{*T}

Note: ^{T} independent t-test; ^{M} Mann-Whitney Test; * statistically significant (p<0,05)

Panoramic radiographs, despite their widespread diagnostic use, exhibit region-specific distortion patterns that significantly impact clinical interpretation. These distortions primarily result from magnification and minimization effects that vary across different jaw regions. While horizontal measurements demonstrate minimization in intermediate upper and median lower quadrants, they show magnification in intermediate and lateral inferior quadrants.[4,18] Vertical measurements, conversely, exhibit consistent magnification across most quadrants.[18]

Our findings demonstrate that anterior mandibular regions on panoramic radiographs primarily experience horizontal reduction while maintaining vertical dimensional accuracy, consistent with previous reports by Farman (2007).[19] The vertical geometric distortion ratios in our study ranged from 1.07-1.09 in anterior regions, 1.10-1.16 in posterior regions, and 1.16-1.21 in mandibular rami.

The focal trough configuration contributes significantly to these regional variations, with anterior regions typically measuring 4.5-12 mm in width compared to posterior regions that are 2-3 times wider.[4] This anatomical relationship makes anterior regions particularly sensitive to patient positioning during image acquisition. The tomographic movement inherent in panoramic radiography, combined with the image receptor-to-focal trough distance, typically produces geometric distortion and magnification approximately 1.3 times actual size.[8,16] However, the degree of vertical and horizontal distortion varies considerably depending on specific X-ray equipment characteristics.[5]

3.2. Oblique Measurement

Table 2 Data and The Result of the Comparison Test on Oblique Measurement

Measurements	Measurements on dry mandibles (A)				Measurements on Panoramic Radiographs (B)				Mean of OPG Distortion (B/A)	p
	Mean	SD	Min	Max	Mean	SD	Min	Max		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
O1A	28.26	2.71	22.56	35.97	33.23	3.33	25.80	40.90	1.18	0.000*T
O1B	28.11	3.03	21.15	34.71	32.90	3.90	24.20	41.00	1.17	0.000*T
O2A	84.91	5.27	73.55	98.02	32.53	11.46	61.90	937.00	1.22	0.002*M
O2B	83.90	5.42	73.84	94.71	86.25	9.04	48.00	106.40	1.03	0.000*T
O3A	58.49	6.86	44.49	87.14	64.53	7.86	49.00	92.30	1.11	0.000*M
O3B	59.94	5.62	46.21	77.24	66.63	8.91	91.30	59.40	1.11	0.000*T
O4A	35.32	4.81	25.37	48.08	38.58	5.13	28.20	50.60	1.09	0.001*T
O4B	34.64	5.03	22.50	47.13	38.06	5.75	25.60	52.70	1.10	0.001*T
O5A	17.04	2.25	11.98	22.36	16.84	2.37	10.80	22.30	0.99	0.639T
O5B	17.28	2.42	11.78	22.49	16.82	2.75	9.50	22.50	0.97	0.349T
O6A	34.50	5.39	21.74	54.35	35.50	4.44	21.60	47.10	1.04	0.101M
O6B	34.19	4.76	24.46	51.50	34.84	5.10	20.20	48.90	1.02	0.229M

Note: T independent t-test; M Mann-Whitney Test; * statistically significant (p<0,05)

Oblique measurements of condylar (O1A and O1B) and posterior mandibular regions (O3A-O4B) showed significant differences ($p < 0.01$) compared to direct measurements. Measurements extending from anterior regions to the coronoid process also demonstrated significant differences ($p < 0.01$), while anterior mandibular measurements (O5A-O6B) showed no significant differences ($p > 0.05$).

Analysis of column (10) in Table 2 reveals that condylar, ramal, and posterior mandibular measurements exhibited image magnification, while anterior measurements near tooth apices (O5A and O5B) showed a slight reduction (0.97-0.99 ratio). Measurements spanning anterior-posterior regions (O2A-O6B) demonstrated distortion patterns similar to posterior-ramal measurements, with magnification ratios ranging from 1.09-1.22.

Contemporary studies report similar distortion patterns in digital panoramic radiography, with particularly pronounced anterior distortion and vertical measurement reduction in incisor regions.[20] Horizontal distortion appears more significant than vertical distortion, especially with altered specimen positioning, as observed in jaw implant studies.[21] These distortions may obscure critical diagnostic features, particularly when oblique lines overlap alveolar crests in periapical radiographs,[22] and can lead to angular measurement discrepancies in mandibular third molar regions.[23]

Despite these limitations, panoramic radiography remains valuable for assessing bone height and structural relationships in posterior jaw regions when proper anatomical distances are maintained.[24] However, clinicians must account for inherent distortions and consider supplemental imaging when precise measurements are required.

The primary factors contributing to image distortion in panoramic radiography are multifaceted, involving both the inherent complexities of the imaging system and the characteristics of the objects being imaged. One significant factor is the dual projection system used in rotational panoramic radiography, which involves simultaneous horizontal and vertical projections that can distort three-dimensional objects in the image. The morphology of the object itself also plays a crucial role; for instance, more rounded objects tend to exhibit less distortion compared to those with more complex shapes. Additionally, the distortion is influenced by the position of the object within the imaging field, with objects located in the anterior region experiencing more pronounced distortion.[8,16]

Our results suggest that standardized patient positioning produces characteristic distortion patterns: anterior regions show primarily horizontal and oblique dimensional changes while maintaining vertical dimensional accuracy. This likely relates to the focal trough's anatomical configuration, which narrows anteriorly and widens posteriorly.[4] Consequently, panoramic radiographs provide more accurate horizontal measurements in posterior regions and anterior-posterior span measurements, while vertical and oblique measurements demonstrate superior accuracy in anterior mandibular regions.

4. Conclusion

This comparative study demonstrates significant measurement discrepancies between panoramic radiographs and direct anatomical measurements of dry mandibles, with distinct regional variations in distortion patterns. The findings reveal that vertical and oblique measurements in posterior mandibular regions (ramus and condylar areas) exhibit clinically relevant magnification ranging from 10% to 22%, while anterior mandibular measurements maintain greater dimensional accuracy, particularly in vertical dimensions (6-9% distortion) and anterior oblique measurements (1-3% distortion). The most pronounced vertical magnification (16-21%) occurred in mandibular ramus measurements, whereas the greatest oblique distortion (17-22%) was observed in measurements spanning from the inter-incisal alveolar crest to the coronoid process. These results corroborate existing literature on panoramic imaging limitations while providing specific quantitative data about regional accuracy variations. The anterior mandible demonstrates superior measurement reliability, supporting its use for clinical assessments requiring vertical dimensional accuracy. Conversely, posterior region measurements require cautious interpretation due to significant magnification effects, particularly for treatment planning involving implants, orthognathic surgery, or TMJ evaluation.

The study highlights the importance of considering panoramic radiography's inherent geometric distortions in clinical decision-making. While remaining an invaluable screening tool due to its accessibility and low radiation dose, clinicians should be aware of its limitations for quantitative assessments in posterior regions. Future studies should investigate correction factors for different panoramic systems and develop standardized protocols to minimize measurement errors in posterior mandibular imaging.

Compliance with ethical standards

Acknowledgements

The authors gratefully acknowledge the Faculty of Dentistry, Universitas Gadjah Mada, for providing financial support for this study.

Conflict of interest statement

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript.

Statement of ethical approval

This study has obtained ethical approval from the Ethics and Advocacy Unit of the Faculty of Dentistry, Universitas Gadjah Mada (Ref. No. 288/KKEP/FKG-UGM/EC/2012). The research complies with all relevant ethical guidelines and regulations concerning the use of human dry mandible samples.

Statement of informed consent

This study utilizes human dry mandible samples, which are non-living anatomical specimens. As such, this research does not involve living human participants or personal health data and therefore does not require ethical approval or informed consent by standard institutional and international guidelines for the use of osteological collections. All samples were obtained and handled in compliance with ethical and legal regulations governing the use of anatomical specimens for scientific research.

References

[1] Parks ET, Williamson GF. Digital radiography: An overview. J Contemp Dent Pr 2002. 2002;3(4):023-039.

[2] Macleod I, Heath N. Cone-Beam Computed Tomography (CBCT) in Dental Practice. Dent Maxilofac Radiol. 2008;(November):590-598. www.impactscan.

[3] Priminiarti M, Kiswanjaya B, Iskandar HB. Radiographic Evaluation of Osteoporosis through Detection of Jaw Bone Changes: A Simplified Early Osteoporosis Detection Effort. Makara J Heal Res. 2011;14(2):51-56. doi:10.7454/msk.v14i2.682

[4] Mudjosemedi M, Widyaningrum R, Gracea S. Perbedaan Hasil Pengukuran Horizontal pada Tulang Mandibula dengan Radiograf Panoramik. Maj Ked Gi Ind. 2015;1(1):78-85. doi:https://doi.org/10.22146/majkedgiind.9010

[5] Gahleitner A, Watzek G, Imhof H. Dental CT: Imaging technique, anatomy, and pathologic conditions of the jaws. Eur Radiol. 2003;13(2):366-376. doi:10.1007/s00330-002-1373-7

[6] Abdi AH, Kasaei S, Mehdizadeh M. Automatic segmentation of mandible in panoramic X-ray. J Med Imaging. 2015;2(4):044003. doi:10.1117/1.jmi.2.4.044003

[7] Langlois C de O, Sampaio MCC, Silva AER, da Costa NP, Rockenbach MIB. Accuracy of linear measurements before and after digitizing periapical and panoramic radiography images. Braz Dent J. 2011;22(5):404-409. doi:10.1590/s0103-64402011000500010

[8] White SC, Michael J Pharoah. Oral Radiology: Principles and Interpretation. 7th ed. (Stuart C White, Pharoah MJ, eds.). Elsevier; 2014.

[9] Akarslan ZZ, Erten H, Güngör K, Celik I. Common errors on panoramic radiographs taken in a dental school. J Contemp Dent Pr. 2003;4(2):024-034.

[10] Widyaningrum R, Faisal A, Mitrayana M, Mudjosemedi M, Agustina D. Imejing diagnostik kanker oral: prinsip interpretasi pada radiograf dental, CT, CBCT, MRI, dan USG. Maj Kedokt Gigi Indones. 2018;4(1):1-14. doi:http://doi.org/10.22146/majkedgiind.22050

[11] Nishikawa K, Suehiro A, Sekine H, Kousuge Y, Wakoh M, Sano T. Is linear distance measured by panoramic radiography reliable? Oral Radiol. 2010;26(1):16-19. doi:10.1007/s11282-010-0038-5

[12] Ong RGK, Stevenson MR. Evaluation of bone density in the mandibles of young Australian adults of Mongoloid and Caucasoid descent. Dentomaxillofacial Radiol. 1999;28(1):20-25. doi:10.1038/sj.dmfr.4600399

[13] Taguchi A. Panoramic radiographs for identifying individuals with undetected osteoporosis. Jpn Dent Sci Rev. 2009;45(2):109-120. doi:10.1016/j.jdsr.2009.05.001

[14] Christopher P, Watanabe A, Farman A, et al. Radiographic Signals Detection of Systemic Disease. Int J Morphol. 2008;26(4):915-926.

[15] Park TW, Choi HM. Implant Radiology in Dental Practice. J Dent. 1982;10(3):266. doi:10.1016/0300-5712(82)90061-6

[16] Whaites E, Drage N. Essentials of Dental Radiography and Radiology. 5th ed. Churchill Livingstone Elsevier, Elsevier Ltd, Toronto; 2013.

[17] Pittayapat P, Galiti D, Huang Y, et al. An in vitro comparison of subjective image quality of panoramic views acquired via 2D or 3D imaging. Clin Oral Investig. 2013;17(1):293-300. doi:10.1007/s00784-012-0698-0

[18] Zúñiga J. Quantification by Quadrants of the Distortion Present in Conventional Panoramic Radiograph. Int J Morphol. 2017;35(1):265-272. doi:10.4067/s0717-95022017000100043

[19] Farman AG. Panoramic Radiology: Seminars on Maxillofacial Imaging and Interpretation.; 2007. doi:10.1097/00006534-199004000-00031

[20] Kayal R. Distortion of digital panoramic radiographs used for implant site assessment. J Orthod Sci. 2016;5(4):117-120. doi:10.4103/2278-0203.192113

[21] Su K, Zhou Y, Hossaini-Zadeh M, Du J. Effects of implant buccal distance on peri-implant strain: A Micro-CT based finite element analysis. J Mech Behav Biomed Mater. 2021;116(January):104325. doi:10.1016/j.jmbbm.2021.104325

[22] Borghetti RL, Nora VP, Costa Filho LC da, Morosolli ARC, Rockenbach MIB. Projection of the oblique line in periapical radiographs of mandibular molars. Rev Odonto Ciência. 2010;25(4):401-405. doi:10.1590/s1980-65232010000400015

[23] Dudhia R, Monsour PA, Savage NW, Wilson RJ. Accuracy of angular measurements and assessment of distortion in the mandibular third molar region on panoramic radiographs. Oral Surgery, Oral Med Oral Pathol Oral Radiol Endodontology. 2011;111(4):508-516. doi:10.1016/j.tripleo.2010.12.005

[24] Stelt P Van der. Modern radiographic methods in the diagnosis of periodontal disease. Adv Dent Res. 1993;7(2):158-162.