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THE ACCURACY OF PANORAMIC RADIOGRAPHY AND CONE BEAM TOMOGRAPHY FOR MEASUREMENT OF THE ANGULATION OF LOWER THIRD MOLAR

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Abstract: **Introduction**: Panoramic radiography (PR) is widely accepted as the method of choice for surgical planning for lower third molars (L3M), however, it is limited by distortions inherent in the images. **Objectives:** The aim of this study was to evaluate the accuracy of PR and cone-beam computed tomography (CBCT) scans in determining the angle of the L3M, estimate the angular distortion caused by the examinations, the appropriate view, and propose the optimum position for the patient's head during the examination for less image distortion. **Materials and Methods:** An in vitro study was performed with a set of 16 molars matched with each other and a dry human jaw osteotomized in the molar region with preservation of the lingual cortical bone to serve as a bed for fixing teeth at angles of 30°, 45°, 60°, and 90° to their long axes. The set was submitted to PR and CBCT imaging examinations changing the Frankfurt plane using a predefined template with angles of 15°, 25°, and 35°. **Results:** The angular difference was less with CBCT compared with the gold standard for 48 images; the difference was statistically significant ($p < 0.05$). **Conclusion:** Compared with the gold standard, the L3M are positioned more vertically on PR, which shows a more mesial position. In this context, a change in the mandibular plane of 35° could presumably minimize this distortion. CBCT is the ideal imaging modality to evaluate the position of L3M.

Keywords: Impacted tooth; Panoramic radiography; Cone-beam computed tomography.

INTRODUCTION

An impacted lower third molar (L3M), the cause of which is unknown, is still common and is characterized by diversity in its formation, morphological variations, eruption time, and high rates of bone retention. This topic is highly relevant and is widely discussed in the dental literature.[1-6]

Tooth eruption follows a sequence of events, from dental germ formation to the interocclusal relationship with the antagonist tooth. The development of a propitious stomatognathic system involves synchronized movements to compensate for size difference of the bone.[7] According to Hattab et al.,[1] if the ratio between the retromolar space and the mesiodistal crown width of the L3M is greater than or equal to 1, then there is a high probability of eruption occurring. In general, L3M eruption occurs in individuals aged between 16 and 24 years.[1,6,8]

The cause of impacted L3M has been investigated by many studies. The lack of retromolar space caused by its late formation,[1,3,9,10] phylogeny of the jaw,[1,10] and condylar growth in the vertical direction associated with low resorption of the anterior edge of the mandibular branch[10] have been highlighted its possible causes. Impacted teeth are frequently associated with pericoronitis, cystic lesions, periodontitis, and neoplasia, in addition to caries and external root resorption in the adjacent tooth.[10-14]

Most studies have found a higher prevalence in women.[2,5,6,11,15-17] This is believed to be due to growth, because the women complete mandibular growth concurrently with eruption of L3M.[9] The prevalence of impacted teeth in different populations and ethnic groups has been the subject of several studies. Studies conducted in Arab countries have reported a prevalence of impacted L3M of 33% to 68.6% of the population. In Canada, the average was 69.5%,[18] and in the United

States the prevalence was 65.6%.[19] According to Quek et al.,[15] 68.6% of L3M were impacted in Singapore. Fardi et al.[7] evaluated a Greek population and found an incidence of 6.2%. In India, 45,8% of L3M were impacted[20]. A Brazilian study identified the occurrence of impacted L3M in 79.6% of its population.[16] It is believed that genetic and racial differences are major factors for impaction.[1,5,10]

Surgical removal of L3M is a common dentoalveolar procedure in oral surgery, for prophylactic, orthodontic, or prosthetic reasons or diagnostic-associated pathologies.[2,6,21] Thus, a thorough preoperative evaluation is important to avoid undesired complications, and, in this context, the use of imaging in the diagnostic evaluation is important. Intraoral radiographs have limited usefulness for surgical planning, because they do not provide enough images of the bone tissue adjacent to L3M and depend on the cooperation of the patient to acquire the correct images. Traditionally, panoramic radiography (PR) and cone-beam computed tomography (CBCT) are the imaging examinations of choice.[17,22]

PR provides an overview of the structures that make up the maxillomandibular complex. It is a fairly simple technique and presents a relatively low radiation dose.[17] Thus, it is widely accepted as the imaging modality of choice for evaluating L3M.[1,17,22-24] However, it presents some distortions because of the projection geometry of the image, which can influence the interpretation and therefore the surgical planning.[17,23,24]

With the computed tomography (CT), the field of oral and maxillofacial radiology has been expanded, allowing greater accuracy in the representation of the anatomic structures. However, CT exposes the patient to a high level of radiation and is more costly than PR, hindering its routine use in dental applications.[17,25] More recently, CBCT has revolutionized dental radiology; it is a sectional technology with dimensional precision that provides professionals with the highest quality diagnostic information at lower cost and lower radiation dose than CT multislice imaging[17], even with L3M.[26]

The aim of this study was to evaluate the accuracy of PR and CBCT in determining the angle of L3M, estimating the angular distortion caused by the examinations. Based on the results, an optimum position for the patient's head during the examination for less image distortion is proposed.

MATERIALS AND METHODS

This experimental research was submitted for consideration to the Research Ethics Committee of the Faculty of Dentistry at the Federal University of Bahia and approved under number CAAE: 27335314.6.0000.5024.

A dry human mandible without anatomic changes, pathologic conditions, or fractures and 16 molar teeth devoid of caries, restoration, fracture or erosion were used.

Mandibular osteotomy was performed in the region of the second and third molar (40 mm in the mesiodistal direction and 20 mm in the buccolingual direction) using a suspension motor for prostheses (Metallurgical Fava, Brazil) and a tungsten carbide drill (Maxcut). The osteotomy procedure removed the vestibular cortical bone and adjacent medullary bone, preserving only the lingual cortical plate, which served for correct positioning of the experimental dental groups, simulating the natural position of teeth. Yellow wax from Asfer was used to fix the units in the bed in the osteotomized area. To define the position of the second molar and the intraosseous bed of the third molar, dashed guidelines were drawn using a BIC Permanent Marker pen for CD and DVD (BIC, Brazil), with a tip of 0.7 mm, in the second and third molar region at the vestibular face of the jaw, perpendicular to its base, and 4 cm from one another, with the aid of a flexible Waleu millimeter ruler.

The 16 dental units was made up of 4 pairs on the right and 4 pairs on the left, simulating the angle between the erupted lower second molar (perpendicular to the mandibular basal bone) and the impacted third molar.

Lines dividing the mesiodistal width of the tooth defined the long axis, and this was marked with gutta-percha tips (Dentsply Maillefer 25 mm thick, fixed by pink JET Classic Self Curing Acrylic Resin) to serve as the reference to determine the angle formed by the intersection of the longitudinal axes. The angles used between the long axis of the two teeth were 30°, 45°, 60°, and 90°, and every angle was achieved using a protractor (Molin) (Figure 01); this measurement was defined as the gold standard (GS). The pairs were fixed to each other with pink JET Classic Self Curing Acrylic Resin.

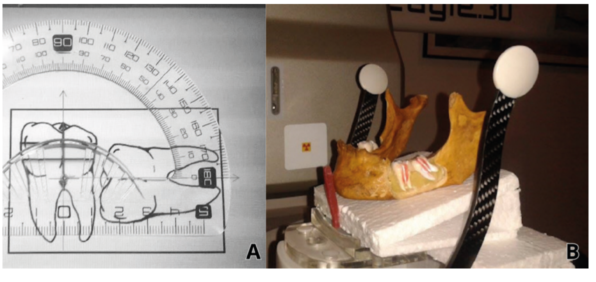

Figure 01. (A) Lines that divide the MD width of the tooth and define the long axis as a reference for demarcating the angulation/90º angle obtained with the intersection of the axes; (B) Mandible on predefined template.

For image acquisition, the jaw was immersed in water in a plastic container for 24 hours before taking the radiographic images, with the intention of filling the medullary spaces. The mandible was positioned on a platform base made of 5-mm-thick Styrofoam on an inclined plane (1 cm). The angles used between the platforms and the horizontal plane (HP) were 15°, 25°, and 35°, simulating positioning of the head at these angles as reference to the mandibular plane, such that the midsagittal plane (MSP) was perpendicular to the HP (Figure 01).

The set was taken to the CT scanner, held in place on the device's cephalostat (Figure 01), and subjected to two image acquisition protocols, panoramic profiles (75.0 kV and 8 mA) and CBCT of the jaw region (voxel size 120 µm, 85.0 kV, and 6.3 mA), in the Eagle 3D equipment, average field of view 12 × 7.5 cm (Dabi Atlante, São Paulo, Brazil). All radiographs and tomographies were performed by a single operator to reduce the possible changes related to technical errors and distortions.

The images were then processed with brightness and contrast tools and subjected to measurement in a darkened room by two examiners (odontologist specialists in radiology and with experience in the diagnosis of maxillomandibular disorders), who had no previous knowledge of the methodology and were familiar with ImageJ software (Maryland, USA) for the panoramic images and On Demand 3D Dental (Irvine, USA) for the tomographic images (Figure 02). Angular tools allowed the slope of L3M about the long axis of the adjacent tooth to be measured.

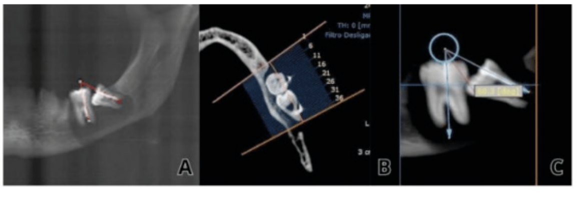

Figure 02. (A) Angular value measured on the panoramic radiograph in the ImageJ software; (B) Study area delimited by the axial section; (C) Panoramic view of CBCT in On Demand 3D Dental with obtaining tooth angulation.

The values of the angulation of impacted L3M were categorized according to Winter's[27] classification (Table 01).

Angular values	Classification
-30º – -5º	Distoangular
-5º – 5º	Vertical
5º – 55º	Mesioangular
55 – 105º	Horizontal

Table 01. Angular values and classification of third molars according to Winter, 1926[27].

Statistical analyses included Lin's concordance coefficient, Pearson correlation coefficient and Student's t test ($p < 0.05$) using R version 3.1.3 to evaluate the potential angular distortions caused by the PR and CBCT images, and to verify the influence of the slope of the mandible on the accuracy of the angular measurements on the images.

In a further analysis, Student's paired t test was used to test the similarity and agreement of the statistical tests using a significance level of $p < 0.05$ and the mean differences.

RESULTS

Forty-eight images, 24 panoramic and 24 CBCT images, were used in this study. The inter-rater agreement was tested using the concordance correlation coefficient proposed by Lin[28,29] to verify the variability between the two angular measurements for both examinations. The rate of agreement was 0.9953 for PR and 0.9887 for CBCT (Figure 03). The accuracy validated by ρ_c indicates that there was almost perfect inter-rater concordance for PR and substantial agreement for CBCT.

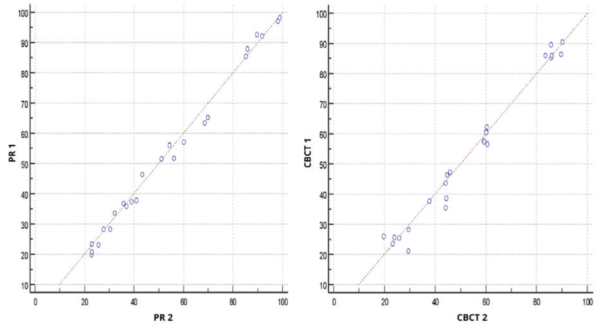

Figure 03. Dispersion of PR angles and inter-rater CBCT angles.

The measurements of the angle formed by inclination of L3M, in the GS, showed variations for both panoramic measurements (Table 02) and CBCT measurements (Table 03) with changes in the mandibular plane.

Of the 24 panoramic images, 14 L3M were categorized as in the mesioangular position and 10 presented horizontal angulation. The tomographic measurements showed that 12 L3M were in the mesioangular position and 12 were horizontally inclined, according to Winter's classification[27].

The tests confirmed the presence of a direct linear relationship between the panoramic angle measurements and the corresponding CBCT measurements, but this difference was not statistically significant (Table 04).

The agreement test showed a greater ρ_c for CBCT, and scatter plots showed the close relationship between the examinations (Figure 04).

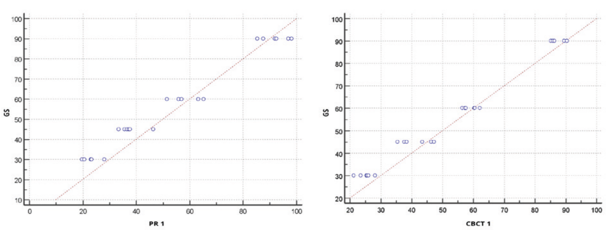

Figure 04. Comparison of the dispersion of panoramic angles and CBCT with the GS.

With the plane at 15º, the correlation coefficients were 0.9499 and 0.9791 for PR

Panoramic Measurement	Mandibular plane					
Dental angle	**15º**	**Mean**	**25º**	**Mean**	**35º**	**Mean**
30º	19,79/23,40	21,60	20,69/23,03	21,86	28,07/28,08	28,07
45º	37,31/33,49	35,40	35,73/36,58	36,15	46,37/37,75	42,06
60º	51,52/55,89	53,70	51,58/57,00	54,29	63,29/65,16	64,22
90º	87,71/85,39	86,55	92,01/92,55	92,28	98,21/97,06	97,63

Table 02. Angular values for right and left sides, respectively, in panoramic examination with variation in mandibular plane.

Tomographic Measurement	Mandibular plane					
Dental angle	**15º**	**Mean**	**25º**	**Mean**	**35º**	**Mean**
30º	25,50/23,50	24,50	26,00/25,40	25,70	21,20/28,20	24,70
45º	47,30/37,60	42,45	43,50/35,40	39,45	46,30/38,50	42,40
60º	57,60/60,30	58,95	57,30/62,20	59,75	56,40/60,50	58,45
90º	85,10/85,90	85,50	85,90/89,50	87,70	86,30/90,40	88,35

Table 03. Angular values of dental unit in CBCT with variation in mandibular plane.

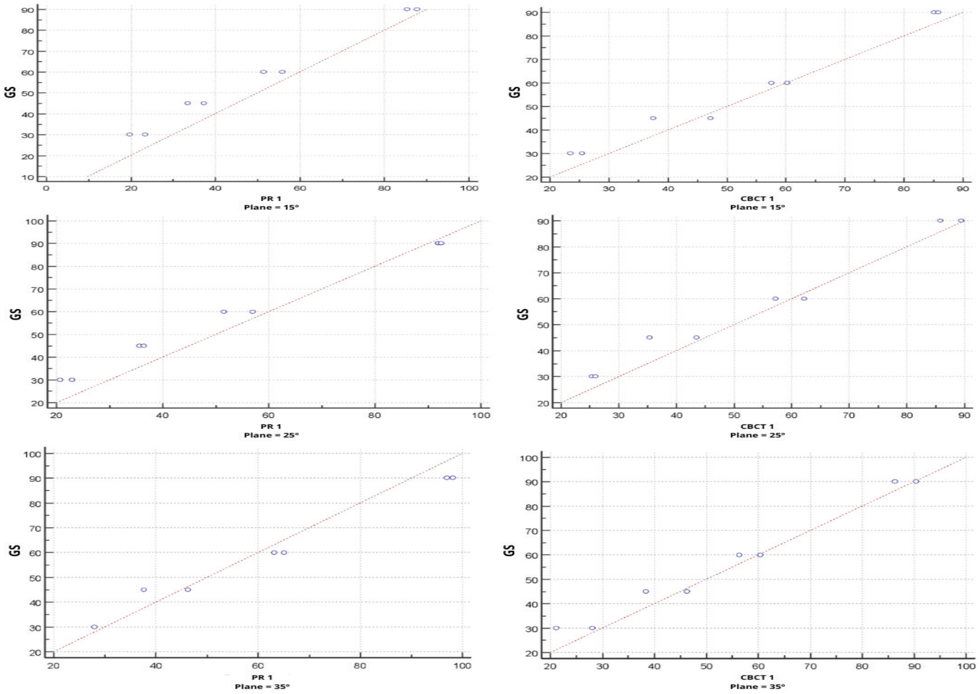

Figure 05. Angular dispersion on different platforms with changes in HP simulating the mandibular plane.

GS (°)	Gold Standard	MP (°)	Panoramic classification	MT (°)	CBCT classification
30	Mesioangular	19,79	Mesioangular	25,5	Mesioangular
45	Mesioangular	35,73	Mesioangular	43,5	Mesioangular
60	Horizontal	63,29	Horizontal	56,4	Horizontal
90	Horizontal	87,71	Horizontal	85,1	Horizontal
30	Mesioangular	20,69	Mesioangular	26,0	Mesioangular
45	Mesioangular	46,37	Mesioangular	46,3	Mesioangular
60	Horizontal	51,52	Mesioangular	57,6	Horizontal
90	Horizontal	92,01	Horizontal	85,9	Horizontal
30	Mesioangular	28,09	Mesioangular	21,2	Mesioangular
45	Mesioangular	37,31	Mesioangular	47,3	Mesioangular
60	Horizontal	51,58	Mesioangular	57,3	Horizontal
90	Horizontal	98,21	Horizontal	86,3	Horizontal
30	Mesioangular	23,4	Mesioangular	23,5	Mesioangular
45	Mesioangular	36,58	Mesioangular	35,4	Mesioangular
60	Horizontal	65,16	Horizontal	60,5	Horizontal
90	Horizontal	85,39	Horizontal	85,9	Horizontal
30	Mesioangular	23,03	Mesioangular	25,4	Mesioangular
45	Mesioangular	37,75	Mesioangular	38,5	Mesioangular
60	Horizontal	55,89	Horizontal	60,3	Horizontal
90	Horizontal	92,55	Horizontal	89,5	Horizontal
30	Mesioangular	28,08	Mesioangular	28,2	Mesioangular
45	Mesioangular	33,49	Mesioangular	37,6	Mesioangular
60	Horizontal	57,00	Horizontal	62,2	Horizontal
90	Horizontal	97,06	Horizontal	90,4	Horizontal

Table 04. Correlation of angular measurements with positional classification of L3M.

	Paired T-Test					Significance level (p-valor)
	Mean	Standard deviation	Standard error mean	Confidence interval - 95%		
GS - PR	**3,43083**	5,79091	1,18207	,98555	5,87612	**,008**
GS - CBCT	**3,0917**	3,3118	,6760	1,6932	4,4901	**,001**
CBCT - PR	**,33917**	5,57624	1,13825	-2,01547	2,69381	**,768**

Table 05. Average in degrees between panoramic measurements and CBCT with GS.

and CBCT, respectively. With the plane at 25°, the coefficient values were 0.9607 for PR and 0.9899 for CBCT. Increasing the angle to 35° clockwise, the correlation coefficients for PR and CBCT were 0.9773 and 0.9821, respectively, and were the highest correlation values obtained (Figure 05).

DISCUSSION

PR is a widely used examination in surgical planning for L3M, however, this imaging modality has limitations that can restrict its use in certain situations, especially with linear and angular distortions in the structures.

The real inclination of L3M over the adjacent second molar is essential for preoperative analysis before extraction, and dentists should be aware of the distortions that this imaging modality can cause.[17,22,23] Odontosections and osteotomies may be indicated, and surgical time and the possibility of resulting trauma may be affected. Yazdani et al.[22] and Dudhia et al.[17] reported that evaluation of the mesial/distal angulation of L3M is of utmost importance for the surgical technique, and that X-ray observations do not always correlate precisely with the clinical findings.

Regarding the position, studies have shown that the most common angles are mesioangular,[5,6,11,15,16,22,23] followed by horizontal.[5] These two most common angulations were analyzed in the present study. Lysell et al.[12] and Venta et al.[30] reported that there is a greater risk of developing disease with distoangular impacted L3M. There was no significant difference between the right and left sides in the current study, corroborating the findings of Hattab et al.,[10] Sant'Ana et al.,[23] and Al-Anqudi et al.[6]

An average difference of 5.37° (±1.46°) between the position of the L3M on PR and the study models made by marking the molar region with silicone during surgery was observed by Sant'Ana et al.[23] Similarly, Yazidani et al.[22] (2009) reported an average difference of 5.75° (±1.65°) using silicone for marking the surgical area before surgery and after the incision to compare the slopes of L3M on X-rays and study models. However, these studies have limitations because it is not possible to accurately define the long axis of L3M when it is under bone and/or submucosal absorption because of the absence of reference points.

Aiming to overcome these limitations, the present study evaluated in vitro the distortion on PR with the most common angular positions of L3M and the sensitivity of CBCT. When PR images were compared with the GS, we obtained an average difference of approximately 3.5° (±1.18°), indicating a more mesial position for L3M, corroborating the findings of Sant'Ana et al.[23] and Yazidani et al.[22] However, in these studies the mean change was greater at 5° and 5.75°, respectively. For CBCT, the average difference was approximately 3° (±0.67°).

Angular distortions arise from vertical and horizontal changes but the horizontal distortions are the most significant. They depend on the synchronous movement of the device, which explains the origin of the modified angulation of the third molars. If a square is projected onto a PR, assuming that the angle between its midpoint and one of the internal angles is the long axis of the third molar, and the vertical line of the square is the long axis of the second molar, the angle is always 45°. On a PR, the image of this square is always distorted, especially in the horizontal direction, thus forming a rectangle. If the same paths are made from the midpoint to the interior angles, taking the vertical lines as a reference, which are considered as the longitudinal axes of the second molars, the angle formed between the center point of the rectangle and any of its internal angles is always less than 45°. This explains the results of the study by Sant'Ana et al.,[23] and the tendency of PR to show a more mesial position of the L3M.

Sant'Ana et al.[23] reported distortion in the position of teeth on PR that may influence surgical planning, however, this does not invalidate it as the main tool for the diagnosis and surgical planning of third molars. Nonetheless, Dudhia et al.[17] state that inherent distortions on panoramic images caused by image projection geometry produce discrepancies in angular measurements in the region of L3M, and interpretation of these with PR is unreliable and does not reflect precisely the actual orientation of the tooth. In this study, two teeth characterized as horizontal on CBCT were measured as being in a mesioangular position on PR, and the relationship of the angulation on PR compared with CBCT demonstrated that CBCT is 100% trustworthy (Table 05). Therefore, it was found that the PR underestimates the angulation of L3M, unlike CBCT.

Although it is not advisable to submit all patients with impacted L3M to CBCT, it is necessary to be careful in interpreting the results of PR.

The spatial orientation of the jaw *in vivo* at the time of PR is 25° to the horizontal plane, based on the mandibular plane. With a variance of 10° clockwise and counterclockwise, it was found that radiographic images with the mandibular plane at 35° had a higher similarity to the GS, presenting the highest correlation coefficients. Thus, it is believed that positioning the patient with the occlusal plane slightly increased clockwise will show less distortion of the position of L3M.

CONCLUSION

CBCT is the ideal imaging modality for evaluating the position of L3M, because it accurately reflects its angulation. PR, due to the infinite possibilities of the patient's positioning, presents angular distortions. During surgery, it must be considered that the L3M will be positioned more vertically when PR suggests a more mesial position.

During the image acquisition, the patient's head should be positioned in the occlusal plane slightly inclined clockwise, resulting in an image where the angulation of the L3M is closer to the real value. At 35° from the Frankfurt plane with the horizontal plane, distortions are minimized, resulting in a dental angular measurement closer to the real value.

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