RESEARCH ARTICLE

Comparison of panoramic radiography and cone beam CT in the assessment of juxta-apical radiolucency

Eduarda Helena Leandro Nascimento, Anne Caroline Costa Oenning, Bernardo Barbosa Freire, Hugo Gaêta-Araujo, Francisco Haiter-Neto and Deborah Queiroz Freitas

Department of Oral Diagnosis, Division of Oral Radiology, Piracicaba Dental School, University of Campinas (UNICAMP), Sao Paulo, Brazil

Objectives: To compare the performance of panoramic radiography (PAN) and cone beam CT (CBCT) in the detection of juxta-apical radiolucency (JAR), as well as to investigate, in CBCT images, if there are factors associated with the detection of JAR on PAN.

Methods: Two oral radiologists assessed the presence of JAR in PAN and CBCT images of 175 individuals (308 mandibular third molars). The cortical plates involvement and the JAR size and location were assessed on CBCT to evaluate if these factors were related to JAR detection on PAN. McNemar's test and multiple logistic regression were performed.

Results: PAN and CBCT differed significantly in the detection of JAR ($p = 0.001$). On PAN, JAR was identified on 24% of the patients while on CBCT its detection increased to 32.6%. JAR was detected only on CBCT and only on PAN in 26 and 7 cases, respectively. Distal/mesial surfaces of dental roots were where JAR was mostly located (84.5%), cortical thinning was found in 59.2% of cases and the mean (SD) of JAR size was 5.03 (± 1.8) mm. However, these factors were not associated with JAR detection on PAN ($p > 0.05$). On the other hand, the location of the cortical involvement (if buccal or lingual) was associated with JAR detection on PAN, which was more detectable when the thinning was on buccal cortical.

Conclusions: Juxta-apical radiolucency is more often detected on CBCT than on PAN. JAR detection on PAN was improved when it was related to the buccal cortical plate of the mandible.

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Keywords: molar, third; alveolar nerve, inferior; panoramic radiography; conebeam computed tomography

Introduction

Pre-operative image evaluation of third molars is essential to clarify the relationship between these teeth and adjacent anatomical structures. Panoramic radiography (PAN) and cone beam CT (CBCT) are the exams often used for this purpose.¹ The choice of these exams must be based on the specific diagnostic requirement following radioprotection criteria, which means that whenever possible two-dimensional modalities are preferable.

However, when a professional deems a complementary examination necessary to provide additional information, which potentially can change treatment plan or post-operative outcomes, CBCT is justified. In general, CBCT is requested for specific cases in which radiographic signs of proximity between the tooth and mandibular canal are observed.²

Juxta-apical radiolucency (JAR) is a radiographic sign characterized by a radiolucent and well delimited image extending from the apex to the lateral root surface of mandibular third molars. JAR detection has been associated with risk of injury to the inferior alveolar

Correspondence to: Miss Eduarda Helena Leandro Nascimento, E-mail: eduarda.hln@gmail.com

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nerve during tooth removal.^{3,4} It refers to an increased space between trabeculae of cancellous bone,⁵ and its prevalence has been reported as 15.6% on PAN.⁶

The two-dimensional characteristic of PAN precludes the assessment of buccal-lingual relationship between dentomaxillofacial structures, which leads to a lack of information on the real relationship between JAR, mandibular canal and mandible cortical plates.⁷⁻⁹ Thus, CBCT might be considered in JAR identification for allowing its three-dimensional evaluation before the surgical procedure, given that JAR represents possible fragility areas around the third molar region.^{6,10}

Despite inherent differences between panoramic and tomographic imaging modalities and their possible interferences in the diagnosis of JAR, recent studies found in the literature only demonstrate cases identified on two-dimensional radiography and secondarily evaluated in CBCT.^{6,10,11} No study has compared its detection in these imaging modalities. In addition, it is still unknown if features such as image overlapping in PAN, trabecular bone appearance in CBCT, or even the anatomical relationship between JAR and mandible cortical plates can influence the detection of JAR in both imaging modalities.

Therefore, the purpose of this study was to compare the detection of JAR in PAN and CBCT images, as well as to investigate if JAR characteristics evaluated on CBCT are associated with its detection on PAN.

Methods and materials

The present study was carried out after the local Institutional Research Ethics Committee approval (074/2015).

The sample was composed of patients who had at least one of the mandibular third molars and had both PAN and CBCT exams. These exams were requested by maxillofacial surgeons for pre-operative surgical planning, independent of this study. Third molars associated with carious lesions, large restorations, endodontic treatment and traumatic injuries (such as bone, dental or alveolar fracture) or with radiographic evidence of intraosseous lesions were excluded. The final sample included 175 patients (66 males and 109 females), aged from 14 to 42 years (average 22.9 ± 4.8), resulting in 308 mandibular third molars.

PAN were obtained using an Orthopantomograph OP100D unit (Instrumentarium Corp., Imaging Division, Tuusula, Finland), operating at 66 kVp, 2.5 mA and exposure time of 17.6 s. CBCT images were acquired using a Picasso-Trio unit (E-WOO Technology Giheung-gu, Republic of Korea), with acquisition parameters selected according to patient's features, mostly age and size (settings ranging from 80 kVp/3.5 mA to 85 kVp/3.7 mA). Nevertheless, in all CBCT exams, the field of view encompassed both mandibular third molar and surrounding tissues, and the voxel size was 0.2 mm. All images were evaluated independently by two oral radiologists, on a 24.1 inch

LCD monitor with spatial resolution of 1.920×1.080 pixels (MDRC-2124, Barco N.V., Courtray, Belgium), under dimmed light conditions. Image adjustment tools (zoom, brightness and contrast) were allowed to simulate clinical situation. When there was disagreement between the two observers, consensus was reached by discussion.

Firstly, all PAN were evaluated for the presence or absence of JAR, which was considered present when a well-defined radiolucent image in the juxta-apical region of mandibular third molars was detected. Subsequently, CBCT images were randomized and the entire volume evaluated in the three orthogonal planes (axial, sagittal and coronal) adjusted according to the long axis of the third molars. All CBCT images were analysed using the EZ3D software (E-WOO Technology Giheung-gu, Republic of Korea) and the minimum slice thickness (0.2 mm) was maintained to standardize the multiplanar evaluations. The observers were asked to evaluate whether JAR was present or absent and determine its predominant location related to dental surface (buccal, lingual, apical, between the dental roots, mesial or distal). JAR was considered in the CBCT exams as a hypodense, well-defined image located adjacent to the third molar roots, detected in more than one multiplanar view.

JAR size was measured by using the working tools of the EZ3D software in three different dimensions (buccolingual, superoinferior and mesiodistal). The largest measurement was used to classify JAR size as: small (< 4 mm), medium (≥ 4 and ≤ 6 mm) and large (> 6 mm) (Figure 1). In addition, the involvement of cortical plates in the JAR region was evaluated using coronal views of CBCT images in order to investigate a possible association of this factor with the detection of JAR on PAN. JAR contact with the cortical (buccal or lingual) was recorded as contact without thinning or when thinning was present and classified according to the amount of remaining cortical bone as J1, J2 and J3 when cortical thickness was $2/3$, $1/2$ and $1/4$ of the maximum cortical thickness, respectively.¹⁰

Thirty days after evaluations, 20% of the sample was reassessed and Kappa test was performed to determine intraobserver agreement using Landis and Koch¹² statement as reference (less than or equal to 0.40, poor

Figure 1 CBCT images showing the measurements of JAR size performed in: (a) mesiodistal dimension (corrected sagittal view); (b) superoinferior dimension (corrected coronal view) and (c) buccolingual dimension (axial view). CBCT, cone beam CT; JAR, juxta-apical radiolucency.

agreement; 0.40–0.59, moderate agreement; 0.60–0.74, good agreement; 0.75–1.00, excellent agreement). Data were analysed using SPSS v.22.0 (SPSS Inc., Chicago, IL). The detection of JAR in PAN and CBCT images were compared using McNemar test. Associations between CBCT findings and JAR detection on PAN were analysed by multiple logistic regression analyses, and a significance level of 5% was adopted.

Results

Intraobserver agreement was excellent for both imaging modalities (Kappa values ranging from 0.821 to 0.903). **Table 1** confronts data obtained from the PAN and tomographic images. JAR detection was significantly different on PAN and CBCT ($p = 0.001$). On PAN, JAR was identified on 24% of patients and 16.9% of the third molars (52 cases - 10 bilaterally and 32 unilateral) while on CBCT its detection increased to 32.6% of patients and 23.1% of the teeth (71 cases - 14 bilaterally and 43 unilateral). In 26 cases, JAR was detected on CBCT but not on PAN. In contrast, only 7 JAR were detected on PAN but not on CBCT. **Figure 2** shows cases of agreement and disagreement between PAN and CBCT.

Table 2 shows CBCT findings related to the detection of JAR on PAN. On CBCT, JAR was located on the distal/mesial aspect of the third molar roots in 60 cases (84.5%) and this location had the highest detection rate on PAN (73.3%). The mean (SD) and the range of the JAR size were 5.03 mm (± 1.8) and 2.0–8.9 mm, respectively. The detection rate increased considerably in cases where JAR was classified as large, reaching 89.5% of detection on PAN. Regarding its involvement with mandibular cortical plates, cortical thinning was found in 59.2% of cases. When JAR was in contact with the buccal cortical on CBCT, its detection rate on PAN was 100%, irrespective of cortical thinning. When JAR was in contact with the lingual cortical, its detection on PAN was null in the absence of thinning, but increased according to the presence and degree of cortical thinning.

The results from multiple logistic regression are shown in **Table 3**. There was no significant association between JAR location related to dental surface ($p = 0.7612$),

JAR size ($p = 0.0541$) or degree of cortical thinning ($p = 0.0523$) and its detection on PAN. However, there was significant association ($p = 0.0050$) between the location of the cortical involvement (buccal or lingual cortical) and JAR detection, which was more detectable when it was located on the buccal cortical.

Discussion

Owing that JAR presence is pointed out as a predictor of injuries to the inferior alveolar nerve, its pre-operative detection is important to estimate the possible outcome related to third molar surgery.^{3–6} In the present study, we found that JAR was more often detected on CBCT than on PAN. This can indicate a possible advantage of performing a CBCT scan for third molars management. When available, three-dimensional imaging modality is important to investigate JAR presence before third molar removal and to determine the surgical approach.^{3,4,8}

Although more cases of JAR have been detected on CBCT than on PAN, a high prevalence was found in both imaging modalities. This can be explained by our sample profile that was composed only of exams for pre-operative assessment of third molars of young patients, resulting in a low mean age, which is in accordance with the results of a previous study.⁶ Up to date, no survey on the performance of CBCT in identifying JAR or its prevalence on this modality has been reported in the literature.

To the best of our knowledge, the present study was also the first to investigate the possible factors related to JAR identification on PAN. Data regarding JAR size and location, and its relationship with the cortical plates were obtained based on CBCT images and subsequently related to the results of PAN images. This investigation was based on two radiographic statements: (1) the overlapping of structures inherent to two-dimensional images could have an impact in the JAR detection; and (2) the fact that detection of a radiolucency in radiographs is more related to the effect that a bone defect has on the cortical than on the cancellous bone.^{13,14}

In a previous study, JAR location had a similar distribution in comparison to observed here. In addition, JAR location was not associated with cortical thinning or with its relationship with the mandibular canal.⁶ In the present study, the highest JAR detection rate on PAN was found when it was located distal/mesial to the third molar (72.9%) while the location between the dental roots showed the worst result (0%). This was expected because areas adjacent to the dental roots present less structures overlapping, which should permit its detection. In contrast, when JAR was located between the dental roots, its distinction from the adjacent bone was a difficult task. Results for the lingual/buccal or apical locations gone down to intermediate values (40% and 50%, respectively), which can be attributed to the overlap of JAR with the tooth and/or the mandibular canal.

Table 1 Contingency table confronting the juxta-apical radiolucency detected in PAN and CBCT

	CBCT n (%)		Total
	Absent	Present	
Panoramic radiography			
Absent	230	26	256 (83.1)
Present	7	45	52 (16.9)
Total	237 (76.9)	71 (23.1)	308 (100)

CBCT, cone beam CT; PAN, panoramic radiography.
 $p = 0.001$, according to McNemar test.

Figure 2 Images from PAN (capital letters) and CBCT in sagittal view (lowercase letters) showing cases where JAR (arrows) was detected on PAN only (Aa), on CBCT only (Bb) and in both imaging modalities (Cc). CBCT sagittal views were used to enable comprehension and comparison of JAR appearance in both imaging methods (PAN and CBCT). CBCT, cone beam CT; JAR, juxta-apical radiolucency; PAN, panoramic radiography.

Until now, no data on JAR size has been found in the literature. However, the method we have applied for JAR measurements was standardized in order to allow the study reproducibility; it was comparable to indices used for evaluation of bone radiolucencies, such as CBCT-PAI (periapical index) for periapical lesions.^{15,16} Although there was no significant difference between JAR size and its detection on PAN, it was observed a

greater propensity to detect JAR in cases where it was classified as large.

Regarding cortical plates involvement, the prevalence of thinning is reported ranging from 46.8 to 70% of the cases,^{6,10} with no differences between buccal and lingual sides.⁶ Our hypothesis is that JAR detection rate on PAN would rise according to the presence and degree of cortical thinning, similar to what occurs in radiographic

Table 2 Descriptive analysis regarding the association between CBCT findings and JAR detection in PAN

CBCT findings (<i>n</i> = 71)	Total	JAR in PAN <i>n</i> (%)			
		Absent		Present	
Location in relation to the third molar					
<i>Buccall/Lingual</i>	4	2	50%	2	50%
<i>Distall/Mesial</i>	60	16	26.7%	44	73.3%
<i>Apical</i>	5	3	60%	2	40%
<i>Between the roots</i>	2	2	100%	0	0%
JAR size					
<i>Small (< 4 mm)</i>	25	10	40%	15	60%
<i>Medium (≥ 4 and ≤ 6 mm)</i>	27	14	51.9%	13	48.1%
<i>Large (> 6 mm)</i>	19	2	10.5%	17	89.5%
Relation of JAR with buccal cortical					
<i>Absence of thinning</i>	18	0	0%	18	100%
<i>J1 (slight)</i>	13	0	0%	13	100%
<i>J2 (moderate)</i>	6	0	0%	6	100%
<i>J3 (severe)</i>	5	0	0%	5	100%
Relation of JAR with lingual cortical					
<i>Absence of thinning</i>	11	11	100%	0	0%
<i>J1 (slight)</i>	11	4	36.4%	7	63.6%
<i>J2 (moderate)</i>	5	0	0%	5	100%
<i>J3 (severe)</i>	2	0	0%	2	100%

CBCT, cone beam CT; JAR, juxta-apical radiolucency; PAN, panoramic radiography.

diagnosis of bone defects such as periapical lesions.¹⁴ Nevertheless, this pattern was observed only when JAR was related to lingual cortical, since detection rates rose dramatically from 0% in the absence of thinning to 63.6% for a slight thinning, and increased to 100% for moderate and severe thinning. In contrast, detection rates on PAN were perfect for all cases of buccal cortical involvement, regardless of the presence or degree of thinning. Probably, this difference in the detection of JAR according to buccal or lingual sides can be related to the proximity of these cortical plates to the imaging sensor. Less radiographic amplification and greater sharpness on the image of structures closest to buccal cortical are expected.

Differences in JAR detection on PAN and CBCT might be related to image formation principles combined with bone structure characteristics. Eventually JAR was identified on PAN and not on CBCT. We believe that this might happen due to different cancellous bone

patterns, which may lead to a non-detection of the JAR on CBCT while the overlapping on PAN could facilitate the detection of JAR borders.

It is well known that the CBCT protocol might have an influence on image quality and diagnostic performance. For this reason, exposure and reconstruction parameters (*i.e.* kVp, mA, number of frames, voxel size) should be carefully selected and controlled, considering the CBCT unit, radiation dose and the diagnostic task. In the present study, CBCT exams were acquired for a specific indication and, therefore, with a small variation of kVp and mA. These parameters are associated with contrast resolution, noise and image quality.^{17,18} Certainly, large variations in these parameters could interfere in the detection of JAR and in the evaluation of its relationship with adjacent structures. However, the limited range of parameters used in the present study is in accordance with the individual characteristics of the patients, CBCT unit, diagnostic task (evaluation of third

Table 3 Multiple logistic regression for possible factors associated with JAR visualization in the PAN

Variable	Coefficient	Standard error	Z	p-value	OR	IC 95%
Intercept	-3.8654	1.5279	—	—	—	—
JAR location related to dental surface	-0.0842	0.2770	-0.3039	0.7612	0.9193	0.53–1.58
JAR size	0.7717	0.4007	1.9259	0.0541	2.1634	0.99–4.74
Degree of cortical thinning	0.6456	0.3327	1.9404	0.0523	1.9072	0.99–3.66
Location of cortical involvement	1.6403	0.5844	2.8070	0.0050 ^a	5.1565	1.64–16.21

JAR, juxta-apical radiolucency; OR, odds ratio; PAN, panoramic radiography.

^aStatistically significant association.

molars) and optimization of exposures. In contrast, the voxel size, which in itself does not interfere in the radiation dose and is mainly related to the spatial resolution of the image, was fixed (0.2 mm) in all exams included in this study. This strategy has met pre-established protocols for pre-surgical evaluation of third molars in this specific CBCT unit.¹⁹ Nonetheless, it should be considered that the choice of the voxel size could interfere mainly in the cortical thinning evaluation, since images with larger voxels are more prone to the partial volume effect related to interpolation of data in a same slice.^{20,21} Therefore, we believe that more studies might be delineated to investigate the influence of these parameters on JAR evaluation.

A key point to consider before choosing an imaging exam is the relation between the effective dose related to it and the information required for diagnosis. However, there is a difficulty in directly estimating the effective dose in different exams, since it is extremely variable depending on technical parameters of the x-rays source and individual factors (*e.g.* age, gender, size and tissue weight factors). Although some current CBCT devices offer small FOVs that allow imaging strictly to the region (tooth) of interest, PAN is the first-choice method for third molars evaluation,²² since it shows both sides of the mandible and is mostly related to smaller effective dose than CBCT.^{23,24} Therefore, despite the benefits of three-dimensional evaluation and the evidence that CBCT provides more information regarding anatomical variations in bone and dental tissues and other possible pathologies related to third molars (*i.e.* external resorption and periodontal bone loss),²² CBCT should only be requested if the additional information can change the treatment planning or the outcome for the patient.²⁵

Subjectivity is present in diagnosis tasks, so it is in the detection of JAR as well. For this reason, we emphasize

the need of practitioners to be acquainted with the presence of this radiographic sign. In addition, we highlight that there were different detection rates concerning imaging modality. CBCT accuracy has been widely discussed in different diagnosis tasks,^{1,9,26,27} with advantages over conventional radiographs, and the absence of image-overlapping can indicate a likely role of CBCT in the detection of JAR. However, patient radioprotection and ALADA principle must be always taken into account.²⁸

Certainly, clinical information might add relevant data regarding patient outcomes in relation to the presence, location and size of JAR and cortical involvement, which is not feasible in most of the cross-sectional studies. In this way, we strongly encourage new clinical studies that could clarify the relation between JAR and possible trans- or post-operative complications and disturbances.

In conclusion, juxta-apical radiolucency is more often detected on CBCT than on PAN. Three-dimensional evaluation allowed higher JAR detection and comprehension of variables related to it, highlighting the value of the CBCT for this purpose. Additionally, cortical plates involvement related to JAR was associated with its identification on PAN, in which buccal involvement increased its detection.

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