Is peripheral cortication of intraosseous lesions accurately displayed on panoramic radiography?

Hugo Gaêta-Araujo, MSc,[a] Larissa Moreira-Souza, MSc,[a] Luciana Asprino, PhD,[b] and Christiano Oliveira-Santos, PhD[c]

Objective. The aim of this study was to calculate the sensitivity, specificity, and positive and negative predictive values (PPV and NPV) for the detection of the presence and continuity of peripheral cortication (PC) around benign intraosseous lesions on panoramic radiography (PR), with cone beam computed tomography (CBCT) as the reference standard.

Study Design. The sample consisted of the mesial, distal, superior, and inferior borders of 40 bony lesions (n = 160) depicted on both PR and CBCT. Ten observers assessed the PRs. CBCT images were assessed by 2 radiologists. For each lesion, observers classified the 4 borders with regard to the presence of PC, and if present, its continuity. Sensitivity, specificity, PPV, and NPV were calculated for the presence and continuity of PC. Intra- and interobserver agreements were calculated.

Results. PR had sensitivity, specificity, PPV, and NPV for PC detection of 0.844, 0.435, 0.435, and 0.844, respectively. With regard to PC continuity, those values were 0.750, 0.810, 0.577, and 0.904. Observer agreement was slight to fair.

Conclusions. The high sensitivity and low specificity for the presence of PC indicate a large false-positive rate. The high NPVs suggest greater validity for negative decisions. The findings corroborate the influence of the eggshell effect. Observer agreement rates indicate that interpretation of PC is substantially subjective. (Oral Surg Oral Med Oral Pathol Oral Radiol 2020;130:725−730)

Panoramic radiography (PR) is usually the first choice of imaging modality when an intraosseous lesion in the mandible or maxilla is clinically suspected or partially observed on an intraoral radiograph.[1] Furthermore, bony lesions are often discovered as incidental findings on PRs of asymptomatic patients.[2] The earliest diagnostic decisions, such as initial differential diagnoses and the indication for additional cross-sectional imaging, are typically based on clinical examinations and 2-dimensional (2-D) radiographs.[3,4]

Radiographically, intraosseous jaw lesions are initially categorized on the basis of the appearances of their internal structure, periphery, location, and effects on surrounding structures.[5] The analysis of the bony periphery of the lesions is essential for diagnosis,[6] and the periphery may be described as either "well-defined" or "ill-defined."[2] The presence of peripheral cortication (PC) indicates a slow-growing pattern (i.e., a well-defined bony margin or sclerotic rim), usually associated with cysts and other benign lesions.[3,7] These lesions can perforate the cortices of the jaws if they reach considerable size.[5] Moreover, when benign lesions have a discontinuous PC, this may indicate secondary infection.[5]

[a]Department of Oral Diagnosis, Division of Oral Radiology, Piracicaba Dental School, University of Campinas (UNICAMP), Sao Paulo, Brazil.
[b]Department of Oral Diagnosis, Division of Oral Surgery, Piracicaba Dental School, University of Campinas (UNICAMP), Sao Paulo, Brazil.
[c]Department of Stomatology, Public Oral Health, Forensic Dentistry, Division of Oral Radiology, School of Dentistry of Ribeirao Preto, University of Sao Paulo (USP), Sao Paulo, Brazil.
Received for publication Feb 10, 2020; returned for revision May 25, 2020; accepted for publication Jun 6, 2020.

2212-4403/$-see front matter
https://doi.org/10.1016/j.oooo.2020.06.008

Most of the currently known radiographic characteristics of lesions are based on 2-D images. PR provides an overall view of the jaws[2,8] with lower radiation dose and cost in comparison with cone beam computed tomography (CBCT).[9] However, PR presents limitations related to distortion, magnification, and overlap of images.[1] Three-dimensional (3-D) imaging can overcome such limitations by providing multiplanar views of the maxillofacial region[10] without superimposition,[1] with high spatial resolution and contrast resolution for bone.[11]

The aim of the present study was to calculate the sensitivity, specificity, positive predictive value (PPV), and negative predictive value (PPV) of the detection of the presence and continuity of PC around benign intraosseous lesions on PR radiographs, with the appearance of the lesions on CBCT exams as the reference standard.

MATERIALS AND METHODS

Sample selection

This study was approved by the local institutional review board (protocol No. 74685517.6.0000.5418). PR and CBCT images acquired between January 2012 and December 2017 were retrieved from the institutional databank and were screened for the presence of radiolucent/hypodense lesions with radiographic characteristics of intraosseous benign noninflammatory,

Statement of Clinical Relevance

Panoramic radiography (PR) may misrepresent the true status of the corticated borders of intraosseous lesions. The validity of interpretation of the presence and continuity of cortication on PRs must be evaluated against cone beam computed tomography, which is the gold standard modality.

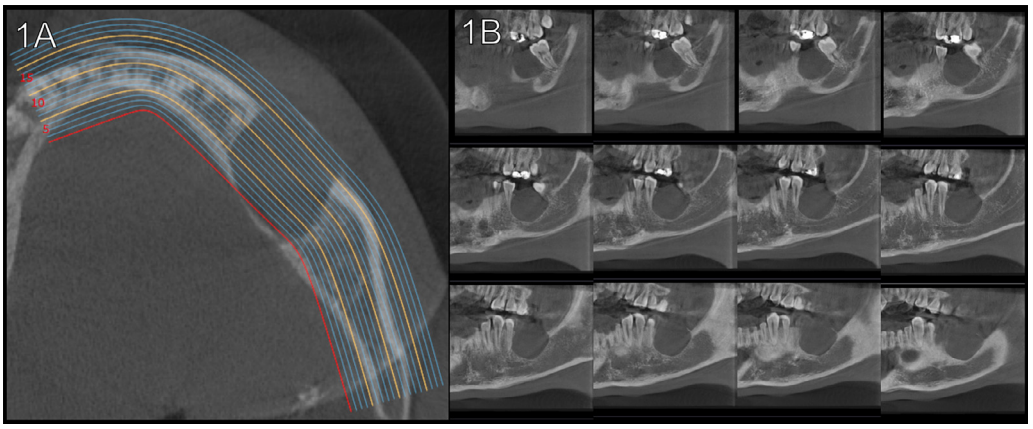

Fig. 1. Representative scheme of the evaluation in cone beam computed tomography (CBCT). An axial slice **(A)** in which a panoramic curve was generated and the subsequent panoramic reconstruction images **(B)** assessed with minimum slice thickness and 1 mm interval between slices. In this case, the inferior periphery of the lesion presents a continuous cortication.

odontogenic, or nonodontogenic lesions of the jaws, with regular, well-defined bony margins. PRs were acquired with an Orthopantomograph OP100 D unit (Instrumentarium Corp., Imaging Division, Tuusula, Finland), with the following exposure parameters: 66 kVp, 2.5 mA, and exposure time of 17.6 seconds. CBCTs were acquired for diagnosis and treatment planning for the lesions identified on the PRs, within 1 month after the PR examination, with a Picasso Trio unit (E-WOO Technology, Giheung-gu, Republic of Korea), with diagnostic task- and patient-specific exposure parameters. Lesions were excluded if they were not entirely encompassed on either of the imaging examinations or if the patients had already undergone any surgical treatment. The sample was composed of the mesial, distal, superior, and inferior borders of the lesions, observed on both PR and CBCT.

Image evaluation

PR images were randomly and independently evaluated in Tagged Image File Format (TIFF) by 10 oral and maxillofacial radiologists with a minimum of 4 years of experience in their specialty, by using JPEG View software v.1.0.35.1 (jpegview.sourceforge.net), in a dimly lit room with an LCD display of 24.1 inches and resolution of 1920 × 1200 pixels (Barco N.V., Courtrai, Belgium). Brightness, contrast, and zoom could be adjusted freely. CBCT images were assessed randomly by 2 oral and maxillofacial radiologists, who were not assigned to examine the PR images. In cases of disagreement, they came to a consensus by using OnDemand3-D software (Cybermed Inc., Seoul, Republic of Korea) on panoramic reconstructions of the CBCT images,[5] with a slice thickness of 0.1 mm and spacing of 1 mm between slices (Figure 1). The observers scrolled through all panoramic slices.

The mesial, distal, superior, and inferior borders of the lesions were assessed for the presence and continuity of PC on both examinations. Data entered by the observers were dichotomous; either "present" or "absent" for the presence of PC, and, if present, either "continuous" or "not continuous" for continuity of the cortication. If a periphery was in contact with a cortex of an anatomic landmark (e.g., the inferior border of the mandible), such information was registered, and continuity was not assessed. On CBCT, PC was considered present if identified in at least 1 slice and not continuous if a discontinuity was discovered in at least 1 slice. To calculate intraobserver agreement, 20% of the sample was reassessed after 6 weeks.

Statistical analysis

Data were analyzed in SPSS version 22 (SPSS Inc., Chicago, IL, USA), with significance level at 5%. For both presence and continuity of PC on PR, modes of the decisions made by the 10 observers were found for each border. If any border had 2 or more equal modes, an 11th observer was assigned to assess the images and break the tie, but this did not occur for any of the images and parameters assessed. For comparison between PR and CBCT, the PCs in contact with anatomic cortices, as observed on CBCT, were excluded from both imaging modalities, and χ^2 and Fisher's exact tests were performed for the presence and continuity of PC, respectively.

Considering CBCT as the reference standard, the diagnostic values of sensitivity, specificity, PPV, and NPV were calculated for data obtained from evaluation of the PRs. Intraobserver agreement was calculated for the CBCT assessment, and both intra- and interobserver agreements were calculated for PR assessment, using

the Kappa coefficient, interpreted according to Landis and Koch.[12]

RESULTS

In total, 160 lesion borders (mesial, distal, superior, and inferior) from 40 lesions were included in the sample (9 in the maxilla and 31 in the mandible), from 37 patients (21 men and 16 women; mean age 24.3 ± 11.9 years). Lesions had radiographic differential diagnoses of dentigerous cyst, simple bone cyst (traumatic bone cyst), residual cyst, odontogenic keratocyst, ameloblastoma, central giant cell granuloma, and odontogenic myxoma.

On CBCT assessments, 66 borders were in contact with anatomic cortices and were not considered for statistical analysis. Those borders were evaluated on PR and were assessed as follows: 25 were considered to have cortication present, and 21 were considered to have cortication absent; and 20 were considered to be in contact with another cortex, in agreement with the CBCT evaluation. For the other 94 borders on PR, 16 were deemed to be in contact with anatomic cortices, and of these, 13 were absent on CBCT. Table I shows the agreement between PR and CBCT for PC presence, with a statistically significant difference between imaging modalities ($P < .001$).

Nearly half the PCs classified as present on PR were actually absent on CBCT, resulting in a large number of false-positive interpretations (Figures 2A and 2B). However, most of the PCs classified as absent on PR were confirmed as absent by CBCT, resulting in a large true-negative proportion (Figures 2C and 2D). Most of the PCs classified as present on PR were confirmed as present by the corresponding CBCT, resulting in a large true-positive proportion (Figures 2E and 2F), but only 2 borders classified as noncorticated on PR were found to be corticated by CBCT (Figures 2G and 2H), yielding a very small false-negative fraction.

There was also a statistically significant difference between the imaging modalities with regard to the continuity of PC ($P < .001$) (Table II). Assessments on PR showed 26 continuous PCs, whereas CBCT assessments revealed 20 continuous PCs, resulting in a large false-positive value. However, 47 borders classified as not continuous on PR were confirmed as not continuous on CBCT, producing a large true-negative fraction. There was agreement between the 2 modalities with regard to the presence of continuous borders in only 15 cases, which produced a somewhat small true-positive value. Only 5 lesions categorized as not continuous on PR were discovered to have continuity on CBCT, leading to a small false-negative value. Cases classified as being in contact with anatomic cortices on PR (n = 16 out of 94 borders) were not included in this statistical analysis.

Diagnostic values for PR were calculated on the basis of the true- and false-positive and true- and false-negative interpretations, with CBCT as the standard reference, and are displayed in Table III. For PC presence, sensitivity and NPV were high (0.844 for both), whereas specificity and PPV were low (0.435 for both). With regard to PC continuity, specificity and NPV were higher (0.810 and 0.904, respectively) than sensitivity and PPV (0.750 and 0.577, respectively).

Mean intraobserver agreement was fair for both presence and continuity in PR assessment (0.350 and 0.336, respectively), whereas interobserver agreement was slight for PC presence (0.161) and fair for PC continuity (0.245). Agreements between the 2 oral and maxillofacial radiologists, who established the CBCT reference standard before consensus, were substantial for PC presence (0.774) and continuity (0.804).

DISCUSSION

The bone margins adjacent to cysts and benign tumors of the jaws are usually described as "well-defined" with corticated borders because of the slow growth pattern of these lesions.[2,5] PRs produced high sensitivity and low specificity for the detection of PC. For the assessment of PC continuity, both sensitivity and specificity were high. NPVs were higher than PPVs for both the presence and continuity of PCs (0.844 vs 0.435 for presence; 0.904 vs 0.577 for continuity). The results indicate that interpretation of PRs can yield many false-positive interpretations for the presence of PC. The large NPVs for both criteria suggest that the false-

Table I. Cross tabulation showing the interpretations of the presence of peripheral cortication as assessed on PR and CBCT

		CBCT			
PR		*Present*	*Absent*	*Contact with cortex**	*Total*
	Present	**27**	22	25	74
	Absent	2	**27**	21	50
	Contact with cortex	3	13	**20**	36
	Total	32	62	66	160

*This column was not considered for statistical analysis.$P < .001$, according to the χ^2 test. Bold numbers in the diagonal represent the cases of agreement between the imaging modalities.*CBCT,* cone beam computed tomography; *PR,* panoramic radiography.

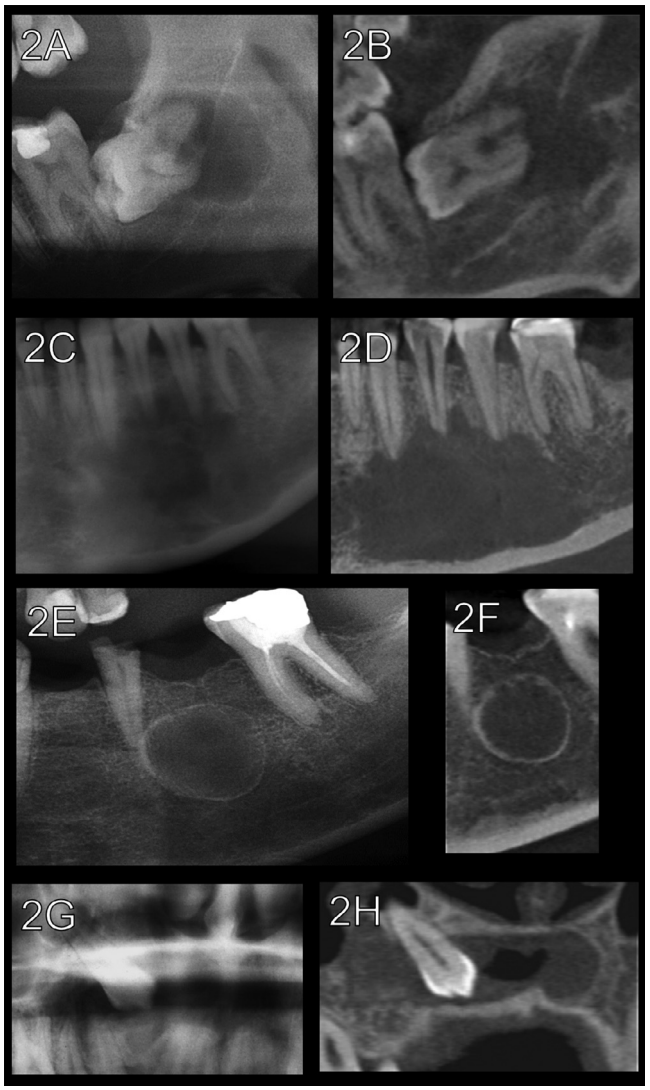

Fig. 2. Cropped images of panoramic radiography (PR) *(left side of each pair)* and cone beam computed tomography (CBCT) *(right side of each pair)* comparing the imaging modalities. **(A, B)** Disagreement between the imaging modalities regarding the presence of peripheral cortication (PC), which was interpreted as present in **(A)** whereas in **(B)** no cortical border was detected with CBCT. This represents a false-positive interpretation. **(C, D)** Absence of cortication on the distal periphery was noted in both imaging modalities (true negative). There is contact between the lesion periphery and the inferior border of the mandible. **(E, F)** Agreement between both modalities for the presence of PC, producing a true-positive interpretation. Continuity in all peripheral limits of the lesion was also detected on PR and CBCT. **(G, H)** Disagreement between imaging modalities for the mesial periphery of the lesion, in which PC was scored as absent on PR but was detected on CBCT (false negative).

Table II. Cross tabulation showing the interpretations of the continuity of peripheral cortication as assessed on PR and CBCT

		CBCT		
		Continuous	*Not continuous*	*Total*
PR	Continuous	**15**	11	26
	Not continuous	5	**47**	52
	Total	20	58	78

$P < .001$, according to Fisher's exact test. Bold numbers in the diagonal represent the cases of agreement between the imaging modalities.
CBCT, cone beam computed tomography; *PR,* panoramic radiography.

negative ratio was smaller than the false-positive ratio for both presence and continuity of PC. Therefore, an interpretation of "absent" or "not continuous" for PC would have more validity than interpretations of "present" or "continuous."

An overestimation of the presence and continuity of PC would be expected because of the eggshell effect. This effect creates a radiopaque line in a 2-D radiograph at the periphery of the 3-D, curved surface of bone, even though the bone at the periphery is no denser than at the rest of the bone surface. This occurs because the x-rays tangential to the bone take a longer

Table III. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) for PR in the detection of PC presence and continuity, with CBCT as reference standard

PR	*Peripheral cortication*	
	Presence	*Continuity*
Sensitivity (95% CI)	0.844 (0.682-0.931)	0.750 (0.531-0.888)
Specificity (95% CI)	0.435 (0.319-0.559)	0.810 (0.691-0.890)
PPV (95% CI)	0.435 (0.319-0.559)	0.577 (0.389-0.744)
NPV (95% CI)	0.844 (0.682-0.931)	0.904 (0.793-0.958)

CI, confidence interval; *CBCT,* Cone beam computed tomography; *PR,* panoramic radiography.

path through the periphery compared with the x-rays that encounter the bone at right angles, and therefore, the tangential photons experience greater attenuation. The overlap of the peripheral areas results in a greater radiopacity around the edge as the 3-D structure is collapsed into the 2-D image.[8] Indeed, the interpretation of our results indicates that the false-positive cases for the presence and continuity of PC on PR in comparison with CBCT would represent the eggshell effect. In total, 22 false-positive results were registered for the presence of PC, and 11 for continuity. Brauer et al.[13] reported a case of odontogenic keratocyst assessed by using both PR and CBCT and observed that the lesion periphery was classified as well-defined and corticated on PR, whereas such cortication could not be identified on CBCT images, and this was attributed to the peripheral eggshell effect.

PC occurs in the marginal bone adjacent to the lesion and, in some cases, it may coincide with anatomic cortices (e.g., the walls of the mandibular canal, inferior border of the mandible, or walls of the maxillary sinus). In our study, when the lesion periphery was in contact with such anatomic cortices, PCs were not considered as present or absent because it is not possible to accurately classify them or distinguish them from the anatomic borders, and therefore, they were excluded from statistical comparisons of the imaging modalities.

Low intra- and interobserver agreement values for PRs revealed that the assessment of the periphery of bony lesions is not straightforward and has a significant degree of subjectivity. Image overlap, magnification, and distortion in PRs may cause misinterpretation of PC characteristics, which may ultimately influence the differential diagnosis. The 3-D nature of CBCT overcomes the limitations of the 2-D PR through multiplanar views of the maxillofacial region.[8] CBCT presents images without superimposition,[2] along with fairly good spatial resolution and sufficient contrast resolution in hard tissues.[9] Moreover, computed tomography (CT), whether multidetector computed tomography (MDCT) or CBCT, is highly suitable for demonstrating the extent of bone resorption, osteosclerosis, and cortical bone enlargement, destruction, and calcification,[14] and this explains the use of CT as the reference standard. CBCT provides more detailed information,[15,16] which may have a beneficial impact on treatment planning and the outcomes of the surgical approach, especially with regard to avoiding complications, functional deterioration, and surgical stress.[4]

Our purpose was to assess the detection and continuity of PC in benign intraosseous lesions as viewed on PR, regardless of the final diagnosis of the lesions. All lesions presented imaging features compatible with noninflammatory, odontogenic or nonodontogenic, benign osteolytic lesions of the jaws, with regular, well-defined, radiolucent patterns. The absence of a final diagnosis based on histology may be considered a limitation of the present study. However, our focus was to determine the reliability of PR in displaying a specific imaging characteristic in comparison with CBCT. Most of the currently known imaging characteristics of lesions are based on conventional images. However, in some cases, the use of PR might be insufficient for a correct differential diagnosis.[15] Future studies should clarify the diagnostic utility of the tomographic features of intraosseous lesions of the jaws on CBCT examinations.

CONCLUSIONS

With CBCT as the reference standard, PR yielded high sensitivity and low specificity for the detection of PC of intraosseous lesions of the jaws, corroborating the influence of the eggshell effect on PR for this diagnostic task. Assessment of lesional peripheries on PR may also underestimate the presence of cortical discontinuities. Fairly low levels of agreement between the observers indicate that interpretations of the presence and continuity of PC are prone to subjectivity.

FUNDING

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, Brazil (CAPES) (Finance Code 001).

REFERENCES

1. Bayrakdar IS, Yilmaz AB, Caglayan F, Ertas U, Gundogdu C, Gumussoy I. Cone beam computed tomography and ultrasonography imaging of benign intraosseous jaw lesion: a prospective radiopathological study. *Clin Oral Investig*. 2018;22:1531-1539.
2. Javadian Langaroodi A, Lari SS, Shokri A, Hoseini Zarch SH, Jamshidi S, Akbari P. Intraosseous benign lesions of the jaws: a radiographic study. *Iran J Radiol*. 2013;10:1-5.
3. Harmon M, Arrigan M, Toner M, O'Keeffe SA. A radiological approach to benign and malignant lesions of the mandible. *Clin Radiol*. 2015;70:335-350.
4. Deana NF, Alves N. Cone beam CT in diagnosis and surgical planning of dentigerous cyst. *Case Rep Dent*. 2017;2017:7956041.
5. Scarfe WC, Toghyani S, Azevedo B. Imaging of benign odontogenic lesions. *Radiol Clin North Am*. 2018;56:45-62.

6. MacDonald D. Lesions of the jaws presenting as radiolucencies on cone-beam CT. *Clin Radiol*. 2016;71:972-985.
7. White SC, Pharoah MJ. *Oral Radiology. Principles and Interpretation*. 7th ed. St. Louis, MO: Mosby/Elsevier; 2013.
8. Pittayapat P, Willems G, Alqerban A, et al. Agreement between cone beam computed tomography images and panoramic radiographs for initial orthodontic evaluation. *Oral Surg Oral Med Oral Pathol Oral Radiol*. 2014;117:111-119.
9. Sakakura CE, Morais JAND, Loffredo LCM, Scaf G. A survey of radiographic prescription in dental implant assessment. *Dentomaxillofac Radiol*. 2003;32:397-400.
10. Shahbazian M, Vandewoude C, Wyatt J, Jacobs R. Comparative assessment of panoramic radiography and CBCT imaging for radiodiagnostics in the posterior maxilla. *Clin Oral Investig*. 2014;18:293-300.
11. Dillenseger JP, Gros CI, Sayeh A, et al. Image quality evaluation of small FOV and large FOV CBCT devices for oral and maxillofacial radiology. *Dentomaxillofac Radiol*. 2016;46:1-10.
12. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics*. 1977;33:159-174.
13. Brauer HU, Diaz C, Manegold-Brauer G. Radiogra1phic assessment of a keratocystic odontogenic tumour using cone-beam computed tomography. *Eur Arch Paediatr Dent*. 2013;14:173-177.
14. Kaneda T, Minami M, Kurabayashi T. Benign odontogenic tumors of the mandible and maxilla. *Neuroimaging Clin N Am*. 2003;13:495-507.
15. Koçak-Berberoğlu H, Çakarer S, Brkić A, Gürkan-Koseoglu B, Altuğ-Aydil B, Keskin C. Three-dimensional cone-beam computed tomography for diagnosis of keratocystic odontogenic tumours: evaluation of four cases. *Med Oral Patol Oral Cir Bucal*. 2012;17:1000-1005.
16. Anbiaee N, Saghafi S, Mohammadzadeh Rezaei M. Central granular cell odontogenic tumor: report of a case with CBCT features. *J Dent (Tehran)*. 2014;11:365-370.

Reprint requests:
Hugo Gaêta-Araujo
University of Campinas
Piracicaba Dental School
Department of Oral Diagnosis
Av. Limeira
901, Zip Code 13414-903
Piracicaba
Sao Paulo
Brazil.
hugogaeta@hotmail.com