RESEARCH ARTICLE

Comparison of panoramic radiography and CBCT to identify maxillary posterior roots invading the maxillary sinus

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Objectives: Given the limitations of panoramic radiography for assessing topographic relationship of maxillary teeth with sinus floor, the purpose of this study was to assess signs on panoramic radiography that could predict root protrusion into the sinus.

Methods: A total of 46 individuals (330 maxillary posterior teeth) who underwent panoramic radiography and CBCT were enrolled. The relationship between the posterior teeth and the maxillary sinus and panoramic radiography signs (projection of the root apices, interruption of the maxillary sinus floor, lamina dura, darkening in the root apices, and superiorly curving sinus floor enveloping the associated tooth root) associated with protrusion of root apices into the sinus were evaluated.

Results: There were differences between the imaging modalities about the positioning of the root apices regarding the sinus ($p < 0.05$). Only the projecting of the root apices and the interruption of the sinus floor on panoramic radiography were predictors for the root protrusion ($p < 0.05$). No significant association was observed for the other panoramic radiography signs ($p > 0.05$).

Conclusions: The root projection into the sinus and the interruption of the sinus floor are indicative signs of root protrusion into the sinus on CBCT.

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Introduction

Surgical removal of upper posterior teeth is a routine procedure in which complications occasionally arise. Oroantral communications might occur after dental extractions, given the anatomical proximity between the upper posterior dental roots and the maxillary sinus. This accident, which has always been a concern for dental practitioners,¹ consists in the violation of the maxillary sinus floor and may or may not involve tearing of the Schneiderian membrane.^{2,3}

The topography of the maxillary sinus floor is extremely variable, with age, maxillary sinus size and maxillary sinus pneumatization being among the factors

that can determine it.^{3,4} Upper posterior roots and the maxillary sinus floor are separated by bone and, not rarely, solely by the sinus mucosa.⁴ In some cases, the thinness of the bone that separates the root apices and the maxillary sinus cortical floor fails to prevent the spread of periapical or periodontal infections into the maxillary sinus.^{3,5} Not surprisingly, endodontic therapy, tooth extraction and orthodontic tooth movement are all potential causes of sinus complications.^{6–8} Histological studies demonstrated that only a thin cortical bone layer envelops most roots that are radiographically protruding into the sinus, with actual mucosal perforations being found in 14–28% of the examined samples.⁹ Therefore, it seems clear that a thorough assessment of maxillary sinus topography is paramount whenever dental implants, extractions, endodontic

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therapy and orthodontics are considered in the posterior maxilla.⁴

The simplest way to assess the relationship between upper posterior roots and the maxillary sinus is through proper imaging of the area. The most commonly used approach is the panoramic radiography, which allows visualization of several anatomical features at low cost and with a relatively low radiation dose.^{10,11} However, the superimposition of anatomical structures, unwanted horizontal and vertical magnification and the absence of cross-sectional information¹⁰ are some of the disadvantages of this technique.¹⁰ In general, panoramic radiography is an unreliable method for determining the relationship between upper posterior teeth and the maxillary sinus.¹ Here, one analogy can be made with the relationship between the third molar and the mandibular canal, which is also unclear in panoramic radiography. On the other hand, some signs revealed by a pre-operative panoramic radiography may alert the attentive surgeon to the need of CBCT imaging before operating on mandibular third molars whose roots may be intertwined with the mandibular canal.¹² CBCT has the advantage of multiplanar, thin-sliced images that are not tainted by superimposition.² Then again, one must bear in mind that radiation dose and costs are higher for CBCT scans, and its use should therefore be reserved for selected cases.

Considering the points highlighted above, the present study attempts to offer a decision-making rationale on the need for pre-operative CBCT scans before den-toalveolar surgery in the posterior maxilla. Our purpose here was two-fold: first, to compare the accuracy of panoramic radiography against that of CBCT in the assessment of the relationship between maxillary posterior teeth and the maxillary sinus, and second, to determine which panoramic radiographic signs, if any, could alert for actual protrusion of dental roots into the sinus cavity.

Methods and materials

Sample

The local research ethics committee approved this work without restrictions (protocol #053/2014). The sample consisted of 330 maxillary posterior teeth of 46 individuals whose records were available in the image database of an oral radiology clinic. Digital panoramic radiographs were acquired with an Orthopantomograph® OP100 D unit (Instrumentarium Corp., Imaging Division, Tuusula, Finland). CBCT images were obtained with a Picasso Trio unit (E-WOO Technology, Giheung-gu, Republic of Korea). Exposure parameters were selected according to patient characteristics and indications for imaging. Individuals with radiological evidence of intraosseous pathology (*e.g.* cysts or tumour), root abnormalities (*e.g.* external reabsorption) or chronic periapical lesions associated

with maxillary posterior teeth were excluded from the study.

Image assessment and scoring

Under dim lighting, two oral radiologists together assessed all images (panoramic radiography and CBCT) with the aid of Windows Photo Viewer (Microsoft, Redmond, WA) on a 14.0-inch light-emitting diode high-definition screen (resolution 1366 × 768 pixels). Examiners were allowed to use the zoom tool and to change the brightness and contrast of the images if they felt necessary. When there was disagreement between the two examiners, a third radiologist was called in to give an opinion. Each imaging technique (panoramic radiography and CBCT) was assessed as a separate subset in a random sequence. The panoramic radiography was the first, and the examiners were blinded about the patient data. Posteriorly, the examiners evaluated the CBCT images in a different sequence from the first imaging modality evaluated. The examiners were also blinded about the patient data.

The relationship between the maxillary posterior teeth and the maxillary sinus floor was evaluated according to the criteria established by Shahbazian *et al.*¹¹ In brief, CBCT and panoramic radiographic images of each tooth, whether single or multirrooted, were attributed a score as follows:

- 0, when there was a distinct space between the root tip and the sinus floor
- 1, when the roots were in close contact with the floor of the maxillary sinus (<0.5 mm away)
- 2, when the roots were projected onto the sinus but were actually lateral or medial to it
- 3, when the roots were protruded into the maxillary sinus cavity (Figure 1).

In panoramic radiographs, Score 3 represented a projection of the root into the sinus cavity. In CBCT images, that same score was defined as the protrusion of the root or roots into the sinus cavity verified in all planes (axial, coronal and sagittal).

In addition, panoramic radiographs were assessed for radiographic signs of projection of the root apices into the sinus cavity, and scored as follows:

- 1, projection of the root apices in the sinus cavity (absent or present)
- 2, interruption of the maxillary sinus floor's cortex (absent or present)
- 3, lamina dura (absent or present)
- 4, darkening of the root apical region (absent or present)
- 5, upward curving of the sinus floor enveloping the tooth root partially or completely (absent or present) (Figure 2).

Statistical analysis

Statistical analyses were performed with the Statistical Package for the Social Sciences SPSS® v. 22 (IBM

Figure 1 Examples of scores (0–3) attributed to the relationship between the maxillary posterior teeth and maxillary sinus floor in panoramic images (a), corresponding CBCT sagittal images (b) and cross-sections images (c).

Corp., New York, NY; formerly SPSS Inc., Chicago, IL). Information from CBCT images was used as the reference standard. Contingency cross-tables with scores given for panoramic radiographic images and for the reference standard, CBCT, were created. The McNemar–Bowker test evaluated the disagreement between the imaging methods, concerning the anatomical relationship between the maxillary posterior teeth and the maxillary sinus floor. A p -value <0.05 indicated the presence of a significant difference.

The null hypothesis considered that there was no disagreement between panoramic radiography and CBCT. Additionally, positive-predictive value (probability of true-positive result occurring) and negative-predictive value (probability of true-negative result occurring) were calculated. Finally, multiple logistic regression was performed to indicate the best predictive radiographic signals regarding the relationship between dental roots vs maxillary sinus floor.

Figure 2 Cropped panoramic radiographs showing each of the tested signs scored as: 1—projection of root apices onto the sinus cavity, 2—discontinuities of the sinus floor, 3—lamina dura, 4—darkening of the root apices and 5—kinks in the sinus floor that envelop a tooth root partially or completely.

Table 1 Contingency table comparing scores of the root–maxillary sinus relationship from CBCT (reference standard) and panoramic radiography (PR)

Imaging modalities / scores		PR				Total
		0	1	2	3	
CBCT	0	85	17	2	5	109
	1	10	38	1	40	89
	2	0	2	2	2	6
	3	1	11	3	111	126
Total		96	68	8	158	330

$p < 0.05$, according to McNemar–Bowker test.

Results

CBCT images indicated that 126 teeth (38%) penetrated into the maxillary sinus cavity, whereas 109 (33%) were at a discernible distance from the maxillary sinus floor.

Panoramic radiography and CBCT scores regarding the relationship between maxillary posterior teeth and maxillary sinus floor are shown in Table 1. In general, 236 (71.5%) cases showed agreement on the positioning in both imaging modalities. Good agreement was verified for 85 (78%) teeth that were distant from the sinus and for 111 (88%) teeth that protruded into the sinus cavity. For scores in the mid-range, there was disagreement between the two modalities, with agreement generally $<50\%$. There was significant disagreement between panoramic radiographs and CBCT, for those teeth with a root projection score of 2 or 3 on the panoramic radiographs, which overestimated the projection of the roots into the sinus. Similarly, panoramic radiographs also tended to underestimate the distance between the roots and the sinus, as seen when comparing teeth with panoramic scores of 0 and 1 and the CBCT of those teeth. However, there was no definitive trend in cases with disagreement.

The negative-predictive value was 0.89, *i.e.* when there is no contact between the root tip and the sinus floor, the panoramic radiography has a high probability to predict it. Regarding the positive-predictive value, the root protrusion into the maxillary sinus (Score 3) demonstrated a 0.70 value. Therefore, the panoramic radiography can also be a potential predictor in this situation. However, the root contact on lateral or medial projections show lower positive-predictive values (0.55 and 0.25, respectively), which can be interpreted as approximately equal to or less than “flipping a coin”. In these cases, panoramic radiography is not particularly useful.

Table 2 summarizes the panoramic radiography signs tested as indicators of an intimate relationship between roots and the maxillary sinus floor. Only the projection of the root apices on the sinus cavity and the interruption of maxillary sinus floor’s cortex were considered as statistically relevant indicators ($p < 0.05$).

Discussion

The immediate relationship between the position of the tip of the root and the maxillary sinus is a predictive factor for oroantral communication. Thus, the proximity between root tips and the maxillary sinus floor may be a reflection of bone resorption caused by chronic apical periodontitis, stage of teeth development, ageing, maxillary sinus pneumatization and the degree of tooth impaction.⁶

The panoramic radiography is the most common diagnostic aid used to assess the proximity between maxillary posterior roots and the maxillary sinus, but assessments of relationship between the upper dental roots and the maxillary sinus showed that panoramic radiography and CT scans differ significantly.^{4,10,11,13} To our knowledge, however, the present work is the first to propose panoramic radiographic signs that could alert the surgeon to possible root protrusions into the maxillary sinus. Our understanding is that despite the problems of image distortion and the lack of sharpness, panoramic radiography is nevertheless useful in most routine clinical situations and is an invaluable tool for determining the need for pre-operative CT scan, as suggested for mandibular third molars.¹² Indeed, the signs chosen in this study as possible indicators of root protrusion into the maxillary sinus were based on information from studies that concerned imaging for third molar surgery^{12,14} and on our clinical observations (kinks in the maxillary sinus floor enveloping part or all of the root, for instance).

The root protrusion into the maxillary sinus was found in 38% of our sample, which is in line with other studies.^{3,11} Actually, it was the most frequent relationship between upper roots and the maxillary sinus, as reported by others.¹⁵ A high correlation between panoramic radiograph and CBCT was found for roots classified with the Score 0, suggesting that panoramic radiography provides enough information for the surgical management of roots that are distant from the

Table 2 Multiple logistic regression for possible radiographic signs indicating root protrusion into the maxillary sinus (MS)

Variable	Standard error	Z	p-value	Odds ratio	95% CI
Intercept	0.28	–	–	–	–
Projection of root onto MS cavity	0.47	8.05	<0.05	44.93	17.79–113.52
MS floor discontinuities	0.39	–2.59	<0.05	0.37	0.17–0.78
Absence of lamina dura	0.37	–0.42	0.6728	0.85	0.41–1.78
Darkening of root apices	0.42	1.25	0.2113	1.69	0.74–3.85
Kinked MS floor enveloping the root	1.47	1.68	0.0929	11.88	0.66–213.19

CI, confidence interval.

maxillary sinus, similar to what Sharan and Madjar¹⁰ concluded in their study. Likewise, agreement was high when roots were protruding into the maxillary sinus; comparable results were reported elsewhere for first molars, second molars and second premolars (84%, 63% and 31%, respectively).¹¹ By contrast, Sharan and Madjar¹⁰ found agreement to be low when the roots protruded into the maxillary sinus. Explanations for such difference may reside in the fact that the latter study evaluated each root individually (in multirrooted teeth) and used a different scoring system with four components to indicate the protrusion of roots instead of the three used here. Consequently, the protrusion could be classified as two scores, which could diverge the results.

Differences between the imaging modalities are clear in borderline cases, in which the roots are very near or in contact with the maxillary sinus floor. For them, assessment with panoramic radiograph is difficult due to superimposition of anatomical structures, ghost image formation, as well as horizontal and vertical distortions.¹⁶ According to Sharan and Madjar,¹⁰ the length of a root protruded into the maxillary sinus is $\times 2.1$ larger in a panoramic radiograph when compared with measures obtained from CT scans. In these cases, the panoramic radiograph will show a large portion of the root projecting onto the sinus cavity, whereas the CT images will show that only the root apex is in contact with the maxillary sinus floor. In another study, CT showed that roots were lateral to the sinus cavity in 7 out of 30 cases, whereas on panoramic radiograph suggested that roots penetrated the maxillary sinus floor.¹⁶

We found interruptions of the maxillary sinus floor in 51% of the cases in which the roots projected into the maxillary sinus. This sign was considered an indicator of actual root protrusion into the maxillary sinus. Similarly, discontinuities of the cortex of the mandibular canal correlated positively with surgical injuries to the inferior alveolar nerve.¹² One must bear in mind, however, that CBCT scans revealed actual root protrusion into the sinus cavity even in cases without discontinuities of the maxillary sinus floor.

In the context of this study, the predictive values obtained indicate that CBCT request is not necessary

when a distinct space between the root tip and the sinus floor was observed on panoramic radiograph, as this imaging modality has been successful in indicating the absence of relationship in most cases. In the same way, when the root is projected onto the sinus on panoramic radiographs, the CBCT request should be weighed, considering that this projection generally signifies the actual root protrusion. This consideration was confirmed by two statistical tests, the high predictive values and multiple logistic regressions, that indicated strong odds ratio for this sign. Therefore, CBCT should not be requested to check the above-mentioned relationship but if the professional would judge it necessary for surgical planning. In cases where the root seems to be in contact or laterally projected onto the sinus on panoramic images that could cause more doubt, the CBCT should be requested for a suitable evaluation, especially in cases of interruption of the cortex of the maxillary sinus floor.

Projection of the root onto the sinus cavity was a strong indicator of an invaded maxillary sinus. Whether actual protrusion of the roots is present or such images result from the negative position of the X-ray beam or from the bidimensional nature of panoramic radiography has always been the subject of debate. Our results demonstrate that, generally, the former is correct. Moreover, the findings reported here reveal that despite the relative lack of accuracy of panoramic radiography, it is still an invaluable tool to determine whether one should ask for a pre-operative CBCT scan. The surgeon must always weigh the risk and benefits of CBCT's higher radiation dose and cost, which strongly justifies the use of panoramic radiography as the primary imaging modality for most routine interventions in the posterior maxilla.

In conclusion, although panoramic radiography does not allow for a precise determination of the topographic relationship between posterior teeth and the maxillary sinus, radiographic signs such as root projection onto the sinus cavity and discontinuities of the sinus floor suggest that roots may be protruding into the maxillary sinus. When surgeons find themselves in doubt in the face of these radiographic signs, asking for CBCT scans in the pre-operative work-up of the posterior maxilla is justified.

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