Original Article

Reliance on Diagnostic Elements in Panoramic Imaging with Focus on Ameloblastoma and Keratocystic Odontogenic Tumor: Psychometric Study

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Abstract

The purpose of this study was to investigate degree of observer reliance (RD) on specific diagnostic elements in differential diagnosis of ameloblastoma (AB) and keratocystic odontogenic tumors (KOT) on panoramic images. The RD for 12 diagnostic elements, including 2 clinical and 10 radiographic elements, as recorded by eight dental radiologists on an ordinal ranking scale, was determined for 9 ABs and 9 KOTs. Intra-observer (IaOC) and inter-observer concordance (IeOC) for both ABs and KOTs were statistically analyzed in terms of RD. Significant differences in IeOC were also investigated between ABs and KOTs. The ranking of diagnostic elements was identified in each case of AB or KOT and classified according to IeOC. The mean rating scores of the 10 radiographic elements were then statistically compared and the RD for radiographic elements classified in each group. Good IaOC and IeOC were identified for the RD for the 12 diagnostic elements. IeOC differed significantly between the AB and KOT groups: the AB group showed higher concordance than the KOT group. Ameloblastoma lesion groups where IeOC was relatively high ($\chi^2 \geq 70$, $70 > \chi^2 \geq 60$) enabled ranking into four groups. Keratocystic odontogenic tumor lesion groups with χ^2 values of ≥ 50 and < 50 showed ranking into five groups and two groups, respectively. In particular, the AB lesion groups showed a highly significant difference for the specified element of “adjacent radicular state”. In panoramic diagnosis, the RD of dental radiologists for diagnostic elements is more consistent for AB than for KOT. In particular, “radicular state adjacent to a lesion” may be a decisive element in distinguishing between AB and KOT.

Key words: Diagnostic elements—Panoramic studies—Psychometrics—
Ameloblastoma—Keratocystic odontogenic tumor

Introduction

Lesions of the jaw bones show a wide range of pathological features. Uni- or multi-locular radiolucent lesions such as ameloblastoma (AB), in particular, and odontogenic keratocysts, which have now been officially reclassified as keratocystic odontogenic tumors (KOT) by the World Health Organization¹⁾, are very difficult to differentiate on panoramic radiographs¹⁰⁾, although this does not apply to desmoplastic AB. Most previous articles focusing on the differential diagnosis of radiolucent jaw lesions on panoramic radiographs have analyzed individual radiographic elements in fragments, such as size, morphological characteristics, marginal conditions, lesion density, location with regard to adjacent tooth structures, radicular state of adjacent teeth, cortical involvement and other factors^{2,6,13–15)}. However, both AB and KOT resemble each other in the image findings for these radiographic elements. Such fragmentary study in panoramic imaging seems to have already reached its limit. In advanced imaging studies, Minami *et al.*⁹⁾ reported the possibility of differential diagnosis between AB and KOT by magnetic resonance imaging. Nonetheless, dental radiologists are frequently required to distinguish between AB and KOT on panoramic radiographs, and this remains the mainstay of initial assessment.

Imaging diagnosis demands that each radiographic element can be accurately identified. As a first step, the dental radiologist will probably attempt to ascertain whether so-called “typical image findings”, based on generally knowledge, are present or not^{5,11,16)}. And then they may also refer to the age and sex of the patient as a potentially indicative clinical element. Whether an image contains or does not contain such typical findings, attention must be paid to specific diagnostic elements, both clinical and radiographic. Unfortunately, the term “typical image findings” does not have a clear definition, and it is entrusted to individual subjectivity, more or less. In other words, making a diagnosis based on image interpretation depends largely on empirical

experience and knowledge of the literature.

The purpose of this study was to investigate degree of observer reliance (RD) on diagnostic elements in differential diagnosis of AB and KOT on panoramic images, and consequently to extract the optimal elements for prioritising between both lesions.

Materials and Methods

A total of 39 panoramic radiographs were randomly selected from the image-data-server at the Department of Oral and Maxillofacial Radiology, Tokyo Dental College. The database allows the dental radiologist to select images arranged according to patient ID number, manifestation localization, clinical and pathological diagnosis or other criteria. The period covered extended from October 2005 to March 2008. These radiographs consisted of 19 ABs (excluding desmoplastic-type AB) and 20 KOTs from the mandibular premolar or molar region. Each image was subjectively assessed by eight dental radiologists (excluding the dental radiologist engaged in the selection of the radiographs) who were all experts in imaging diagnosis. The 39 cases were randomly and individually presented to each radiologist on a computer display under standardized viewing conditions and low ambient lighting. The radiologists, who were blind to the proportions of each type of lesion presented, were then required to distinguish between AB and KOT. The age and sex of the patient were also made known to the radiologists in each case. Two weeks later, they performed the same trial under the same conditions once more. The results were collected on a data sheet and tabulated. The rate of correct diagnosis, reflecting the rate at which imaging diagnosis performed twice in a given case matched the pathological diagnosis in all 8 radiologists, was slightly less than 50%. Consequently, a total of only 18 of the 39 cases (9 ABs, 9 KOTs) for which the image diagnosis from all 8 observers matched the pathological diagnosis, were focused on in this study. Mean subject age was 43.7 years (range, 19–63

years) in the AB group (5 men, 4 women) and 28.2 years (range, 16–48 years) in the KOT group (5 men, 4 women). In this study, all protocols were approved by the Ethics Committee of our institute and informed consent was obtained from all participants.

1. Data acquisition

For the 18 selected cases, the dental radiologists were individually questioned on their degree of reliance (RD) on the following 12 diagnostic elements to determine which elements were taken into consideration:

(Clinical elements)

#1. Age

#2. Sex

(Radiographic elements)

#3. Size

#4. Density (degree of radiolucency)

#5. Marginal shape

#6. Internal composition

#7. Locular state

#8. Expansion state

#9. Configuration

#10. Development direction

#11. An adjacent radicular state

#12. Presence and position of impacted tooth

Simultaneously, each radiologist was informed that the imaging diagnoses carried out twice in the 18 selected cases matched the pathologic diagnosis. The RD for the 12 diagnostic elements was individually recorded using the following scale:

+3 = extremely conscious of element

+2 = very conscious of element

+1 = more conscious of element

0 = conscious of element

–1 = slightly less conscious of element

–2 = not so concerned with element

–3 = almost unaware of element

In terms of matters requiring attention in radiographic elements, the radiologists were assured that extracting the features of the image findings in each case was not the investigational purpose of the study.

2. Data analysis

Initially, analysis of intra-observer concor-

dance (IaOC) and inter-observer concordance (IeOC) on RD for the 12 diagnostic elements was performed using a χ^2 value calculated based on the Kendall concordance coefficient W among 9 ABs (AB group) and 9 KOTs (KOT group). The formula used for χ^2 was as follows:

$$\chi^2 = W \cdot n \cdot (k - 1),$$

where n is the number of cases (*i.e.*, $n=9$)/observers (*i.e.*, $n=8$) and k is the number of elements (*i.e.*, $k=12$). A χ^2 distribution list was used because the number of groups exceeded 4; a Friedman calibration list was not used⁷⁾. Secondly, significant differences in IeOC between ABs and KOTs were determined based on χ^2 values using the Mann-Whitney U test. The tailed *a priori* level of significance was set at $p=0.05$. Third, the ranking of diagnostic elements was summarized in all cases, based on mean rating score obtained for each diagnostic element. The AB and KOT cases were then classified into groups based on the χ^2 values, which determined IeOC. Finally, the mean rating scores for the 10 radiographic elements were then statistically compared using the Wilcoxon matched-pairs signed-rank test and the RD on each radiographic element classified in both groups. The tailed *a priori* level of significance for all tests was set at $p=0.05$. Multiple statistical comparisons were performed using SPSS version 10.1 soft-ware (SPSS, Chicago, IL, USA).

Results

Table 1 shows the IaOC on RD for the 9 cases of AB and 9 cases of KOT, as indicated using the χ^2 value based on the Kendall concordance coefficient W . The χ^2 value ranged from 76.61 to 93.49 for ABs and from 58.14 to 101.34 for KOTs. Table 2 shows the IeOC on RD among the 8 dental radiologists for each case of AB and KOT. The χ^2 value ranged from 44.35 to 73.80 for ABs and from 44.99 to 63.11 for KOTs. In particular, the χ^2 values for ABs were almost always higher than those for KOTs. Statistical analysis using the

Mann-Whitney U test demonstrated that the degree of IeOC differed significantly between ABs and KOTs ($p=0.0106$, Fig. 1). Tables 3A

and B show the results of the ranking of RD for the 12 diagnostic elements in AB and KOT cases, respectively. Tables 4 and 5 show the results of the Wilcoxon matched-pairs signed-rank test among the 10 radiographic

Table 1 IeOC of RD for 9 cases of AB and 9 cases of KOT

Observers	chi square value: χ^2	
	AB group	KOT group
1	93.18 (0.86)	98.26 (0.91)
2	80.37 (0.74)	101.34 (0.94)
3	76.61 (0.71)	79.79 (0.74)
4	84.38 (0.78)	92.08 (0.85)
5	89.07 (0.82)	86.67 (0.80)
6	88.17 (0.82)	63.38 (0.59)
7	93.49 (0.87)	58.14 (0.54)
8	88.58 (0.82)	80.40 (0.74)

The number in a parenthesis is Kendall's W .

$\chi^2 > \chi^2_{0.01} = 24.73$ and $\chi^2 > \chi^2_{0.05} = 19.68$ in both lesion groups demonstrated that each observer showed good consistency in RD on each diagnostic element.

Fig. 1 Inter-observer unevenness of χ^2 values in comparing ABs and KOTs

KOT shows greater degree of inter-observer variability than AB.

Table 2 IeOC on RD among 8 dental radiologists, comparing AB and KOT groups

Lesions	Cases	Age	Gender	chi square value: χ^2
AB group	1	49	M	44.35 (0.46)
	2	59	F	61.29 (0.64)
	3	28	M	70.45 (0.73)
	4	19	F	71.93 (0.75)
	5	62	M	73.80 (0.77)
	6	24	F	56.67 (0.59)
	7	32	M	67.79 (0.71)
	8	58	F	68.91 (0.72)
	9	63	M	64.83 (0.68)
KOT group	1	23	F	45.40 (0.47)
	2	47	M	46.73 (0.49)
	3	19	F	44.99 (0.47)
	4	23	M	56.49 (0.59)
	5	20	F	56.66 (0.59)
	6	16	M	57.01 (0.59)
	7	33	F	63.11 (0.66)
	8	48	M	56.29 (0.59)
	9	25	M	49.71 (0.54)

The number in a parenthesis is Kendall's W .

$\chi^2 > \chi^2_{0.01} = 24.73$ and $\chi^2 > \chi^2_{0.05} = 19.68$ for both lesions demonstrated that 8 dental radiologists showed good consistency in RD for same case.

elements in the AB and KOT groups, respectively (AB: χ^2 values of ≥ 70 , < 70 but ≥ 60 , and < 60 ; KOT: χ^2 values of ≥ 50 and < 50). The boxes attached to each table show that the RD on the 10 radiographic elements was grouped based on the results of the Wilcoxon matched-pairs signed-rank test. The mean rating score for each radiographic element is also given in each box. The number of groupings of RD on the 10 radiographic elements varied in each class of χ^2 values. AB lesion

groups, where χ^2 values were relatively high ($\chi^2 \geq 70$, $70 > \chi^2 \geq 60$), enabled ranking into four groups, although repetition was seen between radiographic elements. In the AB lesion group, with the lowest χ^2 values ($60 > \chi^2$), there was no significant difference between the 10 radiographic elements. Consequently, we were not able to group it. The KOT lesion groups with χ^2 values of ≥ 50 and < 50 showed ranking into five groups and two groups, respectively.

Table 3 A) Ranking of RD on 12 diagnostic elements in AB cases with χ^2 values of ≥ 70 , < 70 but ≥ 60 , and < 60 .
B) Ranking of RD on 12 diagnostic elements in KOT cases with χ^2 values of ≥ 50 , and < 50 .

A)										
Diagnostic elements	$\chi^2 \geq 70$			$70 > \chi^2 \geq 60$				$60 > \chi^2$		Total ranking
	case 29	case 30	case 27	case 35	case 36	case 24	case 38	case 32	case 22	
CE1	10	11	11	10	11	11	10	10.5	10	94.5
CE2	13	12	12	12	12	12	12	12	11	108
RE3	8	8	9	8	7	9	9	8	6	72
RE4	6	5	7	6	6	5.5	6	5	7	53.5
RE5	2	3	4	3	2.5	4	5	1	1.5	26
RE6	7	6	5	5	4	8	7	2	4	48
RE7	1	4	1	7	8	1	3	3	8.5	36.5
RE8	9	9	8	9	9	7	8	9	1.5	69.5
RE9	4	2	3	4	5	5.5	2	4	5	34.5
RE10	5	7	6	2	2.5	2	4	5	3	36.5
RE11	3	1	2	1	1	3	1	7	8.5	27.5
RE12	12	10	10	11	10	10	11	10.5	11	95.5

B)										
Diagnostic elements	$\chi^2 \geq 50$					$50 > \chi^2$				Total ranking
	case 12	case 6	case 8	case 9	case 16	case 28	case 2	case 3	case 4	
CE1	10	11	11	11	10	11	11	11	11	97
CE2	11	12	12	12	12	12	12	12	12	107
RE3	9	7	9.5	8	9	9	10	10	10	81.5
RE4	7	5	6	7	6	6	8	8	8	61
RE5	1	2	2	2	1	1	1	1	2	13
RE6	5	3	1	1	3	3	5.5	6	6	33.5
RE7	4	6	7	4	8	4.5	4	2	1	40.5
RE8	6	8	8	9	4	7	9	7	7	65
RE9	2	4	5	4	2	2	3	3	5	30
RE10	3	1	4	4	5	4.5	5.5	5	4	36
RE11	8	9	3	6	7	10	2	4	3	52
RE12	12	10	9.5	10	11	8	7	9	9	85.5

CE: Clinical element, RE: Radiographic element.

Discussion

Most articles regarding jaw bone lesions with well-defined margins and radiolucency have focused on comparisons between radiographic features such as frequencies of adjacent tooth root resorption¹³⁾, positional relationships between an adjacent tooth and a lesion^{6,14)}, marginal shapes¹⁵⁾, size of lesion and its association with presence or absence of impacted teeth¹⁴⁾ and interior radiographic appearance of the lesion⁹⁾. Ameloblastomas are generally characterized as expansile, with a radiolucent appearance and a smooth periphery, and are often uni- or multiloculated with a characteristic “soap bubble-like” appearance. The lesion can erode the cortex and penetrate the surrounding oral mucosa. In addition, resorption of the roots of adjacent teeth is unique to ABs and indicates an aggressive tumor^{3,4,11,16)}. On the other hand, the radiographic features of a KOT reveal solitary, uni- or multiloculated lesions, often with daughter cysts that extend to the surrounding bone, and well-defined radiolucent lesions with a smooth or loculated periphery^{4,12)}. Keratocystic odontogenic tumors can also expand to cortical bone and erode the cortex⁴⁾. However, we have yet to identify a definitive difference between these two types of lesion on panoramic radiographs as they both generate similar radiographic findings. Hence, the preliminary study for this investigation also resulted in a low rate of correct diagnosis. The sensitivity for ABs was 1.1 times that for KOTs, with barely any difference in diagnostic accuracy between ABs and KOTs.

Kendall's *W* used in this study, known as Kendall's coefficient of concordance, is a non-parametric statistic test for normalization of the statistic of the Friedman test⁷⁾. This test can be used to assess agreement among raters. Kendall's *W* ranges from 0 (no agreement) to 1 (complete agreement), while χ^2 values calculated based on *W* have to be used, depending on the number of items evaluated. In this study, the IaOC and IeOC on RD for diagnostic elements in AB and KOT imaging diagnosis were evaluated using the χ^2 value.

The χ^2 values corresponding to 1% and 5% levels of significance were 24.73 and 19.68, respectively on a χ^2 distribution list. Intra-observer χ^2 values for ABs and KOTs ranged from 76.61 to 93.49 and from 58.14 to 101.34, respectively ($\chi^2 > \chi^2_{0.01}$ and $\chi^2 > \chi^2_{0.05}$). The RD for diagnostic elements during AB and KOT imaging diagnosis showed good IaOC, demonstrating the uniformity of diagnosis among the imaging experts selected for this study. Although the degree of concordance for AB imaging diagnosis was relatively stable, however, a significant unevenness was observed in RD in KOT imaging diagnosis (Table 1). Likewise, inter-observer RD for AB and KOT also showed good concordance, despite some differences in degree in each case. The χ^2 values for each case of AB, however, were almost always significantly higher than those for KOT (Fig. 1, Table 2). In diagnosing AB, an imaging expert generally has coherent criteria to go by, and the conscious weighting of radiographic elements may be more common among dental radiologists than that for KOT. In other words, the dental radiologist is more likely to have a firmly rooted concept of what to look for in making a diagnosis of AB.

Figures 2A and B show AB radiographs with χ^2 values of ≥ 70 or < 70 but ≥ 60 , indicating a higher IeOC. In the best ranking groups for AB (radiographs with χ^2 values of ≥ 70), the RD on element #11 was accompanied by the best rating score (Table 4A), even though there was no adjacent tooth root resorption in some cases: cases 3 and 4. In the second ranking group for AB (radiographs with χ^2 values of $70 > \chi^2 \geq 60$), the RD on element #11 was also independently accompanied by the best rating score (Table 4B). This was probably due to root resorption findings in the adjacent tooth in all cases: cases 2, 7, 8 and 9. Even though case 2 showed a multiloculated appearance with a characteristic “soap bubble-like” appearance, the rating scores for “locular state”, “configuration” and “marginal shape” were remarkably low. Adjacent tooth root resorption is generally listed in any kind of educational text as a characteristic image

Case 5 ($\chi^2 = 73.8$) Case 3 ($\chi^2 = 70.45$) Case 4 ($\chi^2 = 71.93$)

A)

Case 8 ($\chi^2 = 68.91$) Case 7 ($\chi^2 = 67.79$) Case 9 ($\chi^2 = 64.83$) Case 2 ($\chi^2 = 61.29$)

B)

Fig. 2 A) 3 AB cases with χ^2 values of ≥ 70 . B) 4 AB cases with χ^2 values of < 70 but ≥ 60 .

Table 4 Wilcoxon signed ranked test results for AB groups by grade of IeOC

A) p<0.05										
Radiographic elements (REs)	3	4	5	6	7	8	9	10	11	12
3		0.1480	0.0002	0.0039	0.0002	0.0930	0.0001	0.0056	0.0000	0.0000
4	0.1480		0.0835	0.7500	0.0308	0.0581	0.0527	0.3767	0.0090	0.0000
5	0.0002	0.0835		0.0898	1.0000	0.0001	0.8828	0.0137	0.9873	0.0000
6	0.0039	0.7500	0.0898		0.0239	0.0157	0.0157	0.5649	0.0078	0.0000
7	0.0002	0.0308	1.0000	0.0239		0.0001	1.0000	0.0287	0.7725	0.0000
8	0.0930	0.0581	0.0001	0.0157	0.0001		0.0009	0.0020	0.0003	0.0002
9	0.0001	0.0527	0.8828	0.0157	1.0000	0.0009		0.0283	0.5625	0.0000
10	0.0056	0.3767	0.0137	0.5649	0.0287	0.0020	0.0283		0.0393	0.0000
11	0.0000	0.0090	0.9873	0.0078	0.7725	0.0003	0.5625	0.0393		0.0000
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	
Mean rating score	1.21	1.63	2.38	1.75	2.42	0.71	2.38	1.88	2.42	-1.25
<div>RE 12 -1.25</div> <div>RE 8 0.71</div> <div>RE 3 1.21</div> <div>RE 4 1.63</div> <div>RE 4 1.63</div> <div>RE 6 1.75</div> <div>RE 10 1.88</div> <div>RE 5 2.38</div> <div>RE 5 2.38</div> <div>RE 9 2.38</div> <div>RE 7 2.42</div> <div>RE 11 2.42</div>										
B) p<0.05										
Radiographic elements (REs)	3	4	5	6	7	8	9	10	11	12
3		0.0371	0.0011	0.1001	0.0258	0.7044	0.0035	0.0009	0.0000	0.0000
4	0.0371		0.3570	0.5859	0.9536	0.2254	0.3467	0.3019	0.0033	0.0000
5	0.0011	0.3570		0.2678	0.3167	0.0015	0.8326	0.5811	0.0044	0.0000
6	0.1001	0.5859	0.2678		0.7939	0.2164	0.2422	0.1578	0.0009	0.0000
7	0.0258	0.9536	0.3167	0.7939		0.0166	0.3788	0.2488	0.0046	0.0000
8	0.7044	0.2254	0.0015	0.2164	0.0166		0.0131	0.0026	0.0001	0.0000
9	0.0035	0.3467	0.8326	0.2422	0.3788	0.0131		0.9127	0.0029	0.0000
10	0.0009	0.3019	0.5811	0.1578	0.2488	0.0026	0.9127		0.0101	0.0000
11	0.0000	0.0033	0.0044	0.0009	0.0046	0.0001	0.0029	0.0101		0.0000
12	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Mean rating score	0.84	1.34	1.59	1.25	1.34	0.72	1.72	1.69	2.41	-1.34
<div>RE 12 -1.34</div> <div>RE 8 0.72</div> <div>RE 3 0.84</div> <div>RE 6 1.25</div> <div>RE 4 1.34</div> <div>RE 6 1.25</div> <div>RE 4 1.34</div> <div>RE 7 1.34</div> <div>RE 5 1.59</div> <div>RE 9 1.72</div> <div>RE 10 1.69</div> <div>RE 11 2.41</div>										
C) p<0.05										
Radiographic elements (REs)	3	4	5	6	7	8	9	10	11	12
3		1.0000	0.6250	0.3750	0.7500	0.5625	0.7500	0.2500	0.7500	1.0000
4	1.0000		0.6250	0.3125	0.8281	0.5938	0.8125	0.4609	1.0000	1.0000
5	0.6250	0.6250		1.0000	0.1250	1.0000	1.0000	0.5313	0.2500	0.1250
6	0.3750	0.3125	1.0000		0.3750	0.7500	0.9844	0.9063	0.5000	0.5000
7	0.7500	0.8281	0.1250	0.3750		0.5000	0.5000	0.2500	1.0000	1.0000
8	0.5625	0.5938	1.0000	0.7500	0.5000		1.0000	1.0000	0.2500	0.1250
9	0.7500	0.8125	1.0000	0.9844	0.5000	1.0000		1.0000	0.5000	0.3750
10	0.2500	0.4609	0.5313	0.9063	0.2500	1.0000	1.000		0.2500	0.1875
11	0.7500	1.0000	0.2500	0.5000	1.0000	0.2500	0.5000	0.2500		1.0000
12	1.0000	1.0000	0.1250	0.5000	1.0000	0.1250	0.3750	0.1875	1.0000	
Mean rating score	1.50	1.50	1.88	2.00	1.13	1.88	1.88	2.12	1.13	1.13

No significant difference among all elements.

A) For AB group consisting of 3 AB cases in which degree of IeOC was maximal ($\chi^2 \geq 70$). B) For AB group consisting of 4 AB cases in which degree of IeOC was relatively higher ($70 > \chi^2 \geq 60$). C) For AB group consisting of 2 AB cases in which degree of IeOC was low ($60 > \chi^2$).

Fig. 3 5 KOT cases with χ^2 values of ≥ 50

finding for AB^{3,4,11,16}. Struthers and Shear¹³ reported that an AB had a far greater potential for adjacent tooth root resorption than a cystic lesion, which included dentigerous and primordial cysts, which have a similar histopathology to that of odontogenic keratocysts and KOTs. The results of this study indicate that the dental radiologists performed image interpretation accurately while bearing in mind the universally recognized pathognomonic characteristics of AB. This was because the RD on the radiographic element “adjacent radicular state” was equal to or higher than that for “locular state”, “configuration” or “marginal shape”, giving priority to AB.

Figure 3 shows KOT radiographs with χ^2 values of ≥ 50 , indicating a relatively higher IeOC. Five groupings were identified for KOT, with χ^2 values of ≥ 50 (Table 5A). Radiographic elements #12, #3 and #8 were included in the three lower groups, and this result resembled findings for AB. Unfortunately, no prominent radiographic elements characteristic of AB such as “adjacent radicular state” were observed in the KOT groups. No diagnostic element clearly indicative of KOT could be identified from among the dental radiologists, even though the RD on internal composition, marginal shape and development direction was comparatively high. It is interesting that

Table 5 Wilcoxon signed ranked test results for KOT groups by grade of IeOC

Radiographic elements (REs)	3	4	5	6	7	8	9	10	11	12
3		0.0347	0.0004	0.0000	0.0006	0.8539	0.0000	0.0000	0.9615	0.0002
4	0.0347		0.3614	0.0001	0.6879	0.4161	0.1706	0.1072	0.5825	0.0001
5	0.0004	0.3614		0.6965	0.0183	0.0000	0.5197	0.3626	0.0001	0.0000
6	0.0000	0.0001	0.6965		0.0499	0.0061	0.6984	0.8483	0.0079	0.0000
7	0.0006	0.6879	0.0183	0.0499		0.0111	0.0248	0.0177	0.0101	0.0000
8	0.8539	0.4161	0.0000	0.0061	0.0111		0.0029	0.0044	0.9867	0.0004
9	0.0000	0.1706	0.5197	0.6984	0.0248	0.0029		0.7544	0.0015	0.0000
10	0.0000	0.1072	0.3626	0.8483	0.0177	0.0044	0.7544		0.0033	0.0000
11	0.9615	0.5825	0.0001	0.0079	0.0101	0.9867	0.0015	0.0033		0.0005
12	0.0002	0.0001	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0005	
Mean rating score	0.88	1.40	1.95	1.98	1.48	0.90	1.83	1.93	0.93	-0.15
<div>RE 12 -0.15</div> <div>RE 3 0.88</div> <div>RE 8 0.90 RE 11 0.93</div> <div>RE 4 1.40 RE 7 1.48 RE 9 1.83 RE 10 1.93 RE 5 1.95</div> <div>RE 9 1.83 RE 10 1.93 RE 5 1.95 RE 6 1.98</div>										

Radiographic elements (REs)	3	4	5	6	7	8	9	10	11	12
3		0.0777	0.0004	0.0247	0.0000	0.3510	0.0011	0.0003	0.0246	0.5458
4	0.0777		0.0638	0.2131	0.0862	0.9494	0.1028	0.2726	0.1337	0.4830
5	0.0004	0.0638		0.2460	0.4487	0.0001	0.1281	0.1784	0.1607	0.0001
6	0.0247	0.2131	0.2460		0.3584	0.3088	0.5889	0.8867	0.4405	0.3623
7	0.0000	0.0862	0.4487	0.3584		0.0018	0.3912	0.4725	0.4504	0.0021
8	0.3510	0.9494	0.0001	0.3088	0.0018		0.0168	0.0361	0.0144	0.8838
9	0.0011	0.1028	0.1281	0.5889	0.3912	0.0168		1.0000	0.9521	0.0654
10	0.0003	0.2726	0.1784	0.8867	0.4725	0.0361	1.0000		0.8526	0.0566
11	0.0246	0.1337	0.1607	0.4405	0.4504	0.0144	0.9521	0.8526		0.0078
12	0.5458	0.4830	0.0001	0.3623	0.0021	0.8838	0.0654	0.0566	0.0078	
Mean rating score	0.54	1.13	2.00	1.38	1.79	0.79	1.58	1.58	1.54	0.71
<div>RE 3 0.54 RE 12 0.71 RE 8 0.79 RE 4 1.13</div> <div>RE 4 1.13 RE 6 1.38 RE 11 1.54 RE 9 1.58 RE 10 1.58 RE 7 1.79 RE 5 2.00</div>										

A) For KOT group consisting of 5 KOT cases in which degree of IeOC was a little high ($\chi^2 \geq 50$). B) For KOT group consisting of 4 KOT cases in which degree of IeOC was extremely low ($\chi^2 < 50$).

element #5, marginal shape, was ranked highly among the KOT cases, and that the RD on element #11, adjacent radicular state, was considerably lower than that on AB (Table 5A, B). This result resembled that of the lowest AB group ($60 > \chi^2$: Table 4C), which suggests that differentiating KOT was extremely difficult. According to previous studies, KOTs can also resorb teeth, but to a slightly lesser degree

than dentigerous cysts¹⁶⁾, and root resorption of ABs tends to be greater than that of dentigerous cysts¹³⁾. The incidence of radicular resorption in KOTs is commonly recognized as very low. In fact, no cases were suspected of showing positive radicular resorption when we retrospectively reviewed all cases of KOT. Although “adjacent radicular state” on findings of radicular resorption appears to be a deci-

sive element in diagnosing an AB, there were both positive and negative findings for “adjacent radicular state” in diagnosing a KOT, which means that this element may not be a decisive element in such cases. Rather, “marginal shape” may be more important. The comparatively high RD on marginal shape and development direction may have contributed to the lower RD on “adjacent radicular state”. A KOT often exhibits a scalloped margin^{5,16}, and a KOT with a unilocular appearance can exhibit this feature when avoiding the adjacent tooth root⁵, which is not usually accompanied by radicular resorption of the adjacent tooth. Radiographically, a KOT may be unilocular in smaller lesions, but tend towards multilocularity in larger lesions, resulting from growth within the medullary space in a predominantly mesio-distal direction without predominant bucco-lingual expansion³. The typically scalloped appearance of a KOT^{5,16}, which is unrelated to the presence of an adjacent tooth, may be greatly exaggerated by change from a unilocular to a multilocular state with enhancement of lesion size. In Fig. 3, all cases except Case 7 showed small lesions with a unilocular appearance. Even though Case 7 displayed a multilocular state with scalloped margins and larger size, no radicular resorption of an adjacent tooth was observed. Based on experience and general knowledge, dental radiologists probably rely greatly on “marginal shape”, “direction of development” and “configuration”, rather than “adjacent radicular state” in arriving at a diagnosis of KOT.

In panoramic diagnosis, the RD on diagnostic elements is more consistent for AB than for KOT. In particular, “radicular state adjacent to a lesion” may be a decisive element in distinguishing between an AB and a KOT.

References

- 1) Barnes L, Eveson JW, Reichart P, Sidransky D (Eds) (2005) WHO classification of tumours: Pathology and genetics of head and neck tumours, pp. 306–307, IARC Press, Lyon.
- 2) Bernaerts A, Vanhoenacker FM, Hintjens J, Chapelle K, DeSchepper AM (2006) Imaging approach for differential diagnosis of jaw lesions: a quick reference guide. *JBR-BTR* 89: 43–46.
- 3) Bernaerts A, Vanhoenacker FM, Hintjens J, Chapelle K, Salgado R, DeFoer B, DeSchepper AM (2006) Tumours and tumor-like lesions of the jaw: radiolucent lesions. *JBR-BTR* 89: 81–90.
- 4) Dunfee BL, Sakai O, Pistey R, Gohel A (2006) Radiologic and pathologic characteristics of benign and malignant lesions of the mandible. *Radiographics* 26:1751–1768.
- 5) Farman AG, Nortje CJ, Woo RE (1993) Oral and Maxillofacial Diagnostic Imaging. pp. 217–219, Mosby, St. Louis.
- 6) Ikeshima A, Tamura Y (2002) Differential diagnosis between dentigerous cyst and benign tumor with an embedded tooth. *J Oral Sci* 44:13–17.
- 7) Kendall MG, Babington-Smith B (1939) “The Problem of m Rankings”. *The Annals of Mathematical Statistics* 10:275–287.
- 8) Kim SG, Jang HS (2001) Ameloblastoma: A clinical, radiographic, and histopathologic analysis of 71 cases. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 91:649–653.
- 9) Minami M, Kaneda T, Ozawa K, Yamamoto H, Itai Y, Ozawa M, Yoshikawa K, Sasaki Y (1996) Cystic lesions of the Maxillomandibular Region: MR imaging distinction of odontogenic keratocysts and ameloblastomas from other cysts. *AJR Am J Roentgenol* 166:943–949.
- 10) O’Reilly M, O’Reilly P, Todd CEC, Altman K, Schfler K (2000) An assessment of the aggressive potential of radiolucencies related to the mandibular molar teeth. *Clin Radiol* 55:292–295.
- 11) Som PM, Curtin HD (2003) Head and Neck Imaging, 4th ed., pp. 349–352, 354–356, 946–948, Mosby, St. Louis.
- 12) Steven BB (1997) Odontogenic keratocyst: review of the literature and report of a case. *J Periodontol* 68:306–311.
- 13) Struthers P, Shear M (1976) Root resorption by ameloblastomas and cysts of the jaws. *Int J Oral Surg* 5:128–132.
- 14) Tsukamoto G, Makino T, Kikuchi T, Kishimoto T, Nishiyama A, Sasaki A, Matsumura T (2002) A comparative study of odontogenic keratocysts associated with and not associated with an impacted mandibular third molar. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 94:272–275.
- 15) Tsukamoto G, Sasaki A, Akiyama T, Ishikawa T, Kishimoto K, Nishiyama A, Matsumura T

- (2001) A radiologic analysis of dentigerous cysts and odontogenic keratocysts associated with a mandibular third molar. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 91:743–747.
- 16) White SC, Pharoah MJ (2004) *Oral Radiology, principles and interpretation*, 5th ed., pp. 419–420, Mosby, St. Louis.

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