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A clinicopathological and surgical outcome correlation in odontogenic cysts using AI-based radiographic analytics

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Abstract:
Radiolucent odontogenic cysts often show overlapping imaging features, making pre-operative diagnosis challenging. Therefore, it is of interest to evaluate the artificial intelligence (AI) radiographic model against histopathology in 100 cases. The model showed 88% diagnostic agreement with histopathology, with higher confidence in concordant predictions than discordant cases (90.1% vs. 68.5%, $p < 0.001$). Radicular cysts were most common (63%), while keratocysts showed significantly greater volume and mean radiodensity ($p \leq 0.002$) and higher recurrence (33.3% vs. 4.4%, $p = 0.015$). Thus, the AI model showed useful diagnostic performance and calibration as a decision-support tool while maintaining histopathology as the diagnostic reference standard.

Keywords: Odontogenic cysts, artificial intelligence, deep learning, cone-beam computed tomography, histopathology, odontogenic keratocyst

Background:
Odontogenic cysts are common pathological lesions of the jaws and are broadly classified into inflammatory and developmental categories **[1].** Epidemiological studies consistently report radicular cysts as the most frequent subtype, followed by dentigerous cysts and odontogenic keratocysts **[2].** Although most lesions are benign and can be treated conservatively, odontogenic keratocysts demonstrate locally aggressive behaviour and a higher recurrence risk, influencing treatment and follow-up **[3].** Histopathological examination remains the definitive method for diagnosis, while imaging is essential for preoperative assessment and treatment planning **[4].** However, overlapping radiographic characteristics, including unilocular or multilocular radiolucency, variable borders and association with impacted teeth, can make differentiation between cystic lesions difficult **[4].** Quantitative imaging parameters, including lesion volume and radiodensity measured on cone-beam computed tomography (CBCT), may improve differentiation among odontogenic cysts **[5]**. Artificial intelligence (AI), particularly deep learning and convolutional neural networks, has showed promising performance in detecting and classifying odontogenic lesions on panoramic and CBCT images **[6]**. Object-detection and machine-learning approaches have further demonstrated potential for identifying jaw lesions and differentiating odontogenic keratocysts from other pathological entities **[7].** AI has also been investigated in the analysis of histopathological images and in systematic evaluations of odontogenic cyst detection and classification **[8]**. However, limited evidence directly compares AI-based radiographic diagnoses with histopathological findings in clinical cohorts or evaluates whether model confidence can identify potentially uncertain diagnoses **[9]**. Therefore, it is of interest to evaluate the concordance of an AI-based radiographic diagnostic model with histopathology across odontogenic cysts, along with imaging biomarkers, treatment patterns and follow-up outcomes.

Methodology:
This diagnostic accuracy study analysed 100 consecutive patients with jaw radiolucency clinically and radiographically consistent with an odontogenic cyst that underwent surgical management with histopathological examination. For each patient, age, sex, presenting symptom, lesion location and associated tooth status and impacted-tooth association were recorded, together with radiographic descriptors comprising greatest dimension, locularity, border definition, cortical expansion and adjacent root resorption. Each lesion was

processed by an AI radiographic diagnostic model applied to the CBCT and panoramic imaging. The model segmented the lesion and derived its volume (cm^3) and mean radiodensity (Hounsfield units), then produced a predicted diagnosis together with a softmax confidence score for the predicted class. The AI prediction was compared with the final histopathological diagnosis, which served as the reference standard and each case was classified as concordant or discordant. Definitive surgical procedure, post-operative complications, follow-up duration, recurrence and radiographic bone-healing outcome were also recorded. The primary outcome was the overall diagnostic accuracy of the AI model, defined as the proportion of cases concordant with histopathology, reported with a 95% Wilson confidence interval. Per-diagnosis sensitivity was calculated for each histopathological category. Secondary analyses examined AI confidence in concordant versus discordant cases, AI-derived imaging biomarkers by diagnosis and treatment and follow-up outcomes. Analyses were performed in Python (SciPy/statsmodels). Continuous variables were summarised as mean ± standard deviation. Normality was assessed with the Shapiro–Wilk test; confidence scores and sizes between concordant and discordant groups were compared with the Mann–Whitney U-test and imaging biomarkers across the three commonest diagnoses with the Kruskal–Wallis test. Categorical associations, including recurrence by diagnosis, were tested with the chi-square or Fisher exact test. Significance was set at $p < 0.05$.

Results:

The demographic and clinical profile is shown in **(Table 1).** The 100 patients had a mean age of 38.5 ± 13.0 years, with a slight male predominance (56%). Swelling (41%) and pain (30%) were the commonest presentations, while 16% of lesions were incidental findings. Most lesions were associated with a non-vital tooth (72%) and one quarter was related to an impacted tooth. Radiographic and lesion features are summarised in **(Table 2)** the mean greatest dimension was 19.7 ± 10.0 mm, most lesions were unilocular (82%) and well-defined corticated borders were the commonest margin (59%), with cortical expansion in 43% and root resorption in 28%. The distribution of histopathological diagnoses and the corresponding AI predictions are given in **(Table 3).** Radicular cysts were the most frequent lesion (63%), followed by dentigerous cysts (17%) and odontogenic keratocysts (9%), a spectrum consistent with reference epidemiology. The AI model reproduced this distribution closely. Diagnostic performance is presented in **(Table 4).** The AI model correctly identified the histopathological diagnosis with a per-lesion sensitivity of 87% for radicular cysts, 88% for dentigerous cysts and 89% for odontogenic keratocysts, with the few errors concentrated among the rarer entities. Overall concordance with histopathology **(Table 5)** was 88% (95% CI 80.2–93.0). Importantly, AI confidence was substantially higher in concordant than in discordant predictions (90.1% versus 68.5%, $p < 0.001$), so that low confidence effectively flagged cases at risk of misclassification; neither locularity nor lesion size was significantly associated with concordance. AI-derived imaging biomarkers differed significantly across the three commonest cyst types **(Table 6)**. Mean lesion volume increased from radicular (1.58 cm^3) to dentigerous (5.99 cm^3) to keratocyst (9.17 cm^3) and keratocysts showed the highest mean radiodensity (34.7 HU) (volume $p < 0.001$; radiodensity $p = 0.002$). Management and outcomes are summarised in **(Table 7)** enucleation, alone or combined with curettage, apicectomy or peripheral ostectomy with Carnoy's solution, was the dominant treatment. Post-operative complications were infrequent (7%), complete radiographic healing was achieved in 64% over a mean follow-up of 20.7 months and overall recurrence was 7%. Recurrence was strongly diagnosis-dependent: odontogenic keratocysts recurred in 33.3% of cases compared with 4.4% of all other cysts combined ($p = 0.015$).

Table 1: Demographic and clinical presentation of the cohort (n = 100)

Variable	Category	n (%)
Age (years), mean ± SD	–	38.5 ± 13.0
Sex	Male	56 (56%)
	Female	44 (44%)
Presenting symptom	Swelling	41 (41%)
	Pain	30 (30%)
	Asymptomatic (incidental)	16 (16%)
	Discharge / sinus	13 (13%)
Associated tooth status	Non-vital	72 (72%)
	Associated impacted tooth	21 (21%)
	Vital	7 (7%)
Impacted-tooth association	Yes	25 (25%)

Lesion location (not shown): mandible posterior 35%, maxilla anterior 27%, mandible anterior 20%, maxilla posterior 18%.

Table 2: Radiographic and lesion characteristics

Feature	Category	n (%)
Greatest dimension (mm), mean ± SD	–	19.7 ± 10.0
Locularity	Unilocular	82 (82%)
	Multilocular	18 (18%)
Border definition	Well-defined corticated	59 (59%)
	Well-defined non-corticated	28 (28%)
	Ill-defined	13 (13%)
Cortical expansion	Present	43 (43%)
Root resorption	Present	28 (28%)

CBCT/OPG-derived descriptors.

Table 3: Histopathological (reference standard) versus AI-predicted diagnosis distribution

Diagnosis	Histopathology, n	AI predicted, n
Radicular cyst	63	56
Dentigerous cyst	17	19
Odontogenic keratocyst (OKC)	9	10
Residual cyst	5	6
Calcifying odontogenic cyst	3	4
Glandular odontogenic cyst	2	3
Lateral periodontal cyst	1	2

Histopathology served as the reference standard for all comparisons.

Table 4: AI per-diagnosis sensitivity against histopathology

Histopathological diagnosis	n	Correctly identified, n (%)
Radicular cyst	63	55 (87%)
Dentigerous cyst	17	15 (88%)
Odontogenic keratocyst (OKC)	9	8 (89%)
Residual cyst	5	5 (100%)
Calcifying odontogenic cyst	3	3 (100%)
Glandular odontogenic cyst	2	1 (50%)
Lateral periodontal cyst	1	1 (100%)

Sensitivity = correct AI predictions divided by histopathologically confirmed cases in each category.

Table 5: Overall AI diagnostic performance and confidence calibration

Metric	Value
Overall concordance with histopathology	88/100 = 88.0% (95% CI 80.2–93.0)
Mean AI confidence – all cases	87.5 ± 8.7%
Mean AI confidence – concordant cases	90.1 ± 4.8%
Mean AI confidence – discordant cases	68.5 ± 7.5%
Confidence: concordant vs discordant (p-value)	<0.001*

*Mann–Whitney U test; * significant at p ≤ 0.05. Wilson method used for the 95% confidence interval.*

Table 6: AI-derived imaging biomarkers by major diagnosis (mean ± SD)

Diagnosis	Volume (cm^3)	Radiodensity (HU)	Size (mm)
Radicular cyst	1.58 ± 2.38	21.7 ± 8.8	15.6 ± 8.0
Dentigerous cyst	5.99 ± 5.31	19.6 ± 10.3	27.4 ± 8.6
Odontogenic keratocyst (OKC)	9.17 ± 5.51	34.7 ± 8.5	32.5 ± 6.6
p-value (Kruskal–Wallis)	<0.001*	0.002*	–

*Kruskal–Wallis test across the three commonest diagnoses; * significant at p ≤ 0.05.*

Table 7: Surgical management and follow-up outcomes

Outcome	Category	n (%)
Surgical procedure	Enucleation	52 (52%)
	Enucleation + curettage	25 (25%)
	Enucleation + apicectomy	16 (16%)
	Enucleation + peripheral ostectomy + Carnoy's	5 (5%)
	Marsupialization then enucleation	1 (1%)
	Segmental resection	1 (1%)
Post-op complication	Any	7 (7%)
Bone healing	Complete radiographic healing	64 (64%)
	Partial healing (ongoing)	26 (26%)
Recurrence	OKC	3/9 (33.3%)
	All other cysts	4/91 (4.4%)

Mean follow-up 20.7 ± 8.8 months. OKC versus non-OKC recurrence: Fisher exact test, p = 0.015.

Discussion:

This study showed 88% concordance between the AI radiographic model and histopathological diagnosis, supporting the potential of AI for odontogenic cyst classification. These findings are consistent with previous studies showing promising performance of AI and deep-learning models using panoramic and CBCT images for detecting and differentiating odontogenic lesions **[7]**. Diagnostic performance was generally better for common cysts than for rarer lesions, consistent with previous reports highlighting the influence of lesion prevalence and training-data availability on AI classification **[8, 9]**. Importantly, AI confidence was significantly higher in concordant than discordant cases, suggesting that low-confidence predictions could help identify lesions requiring additional radiological assessment and histopathological confirmation. Similar evidence supports the use of AI as a decision-support tool rather than a replacement for definitive diagnosis **[10,11]**. Imaging biomarkers also showed significant differences between cyst types, with keratocysts demonstrating greater lesion volume and mean radiodensity. These findings support the potential value of quantitative CBCT parameters in improving radiographic differentiation of odontogenic cysts **[12]**. Radicular cysts were the most frequent lesions, followed by dentigerous cysts and keratocysts, consistent with established epidemiological patterns **[13]**. Keratocysts demonstrated significantly higher recurrence, supporting their recognized aggressive behaviour and the need for careful long-term follow-up. Overall, the combination of diagnostic concordance, confidence calibration and imaging biomarkers indicates that AI may provide useful adjunctive support in odontogenic cyst diagnosis and clinical decision-making **[14]**. However, multicentre external validation and prospective comparison with experienced radiologists are required before routine clinical implementation.

Conclusion:

The AI model achieved 88% diagnostic agreement with histopathology, demonstrating promising accuracy and reliable identification of uncertain cases. AI-derived volume and radiodensity supported cyst differentiation, while odontogenic keratocysts exhibited higher recurrence. AI-assisted radiographic assessment may improve diagnostic efficiency and risk stratification while preserving histopathology as the diagnostic standard.

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