Review Article

# Performance of Different Radiographic Modalities in Identifying Odontogenic Cysts and Tumors: A Systematic Review and Meta-Analysis

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## ABSTRACT

### Background

Radiographic diagnosis of odontogenic cysts and tumors requires proper diagnosis to facilitate successful treatment. Although many types of imaging modalities exist, the relative diagnostic performance of these modalities is not well established.

### Methods

This paper sought to review the literature on the effectiveness of panoramic radiography, CBCT, and CT to detect these jaw lesions. It was a systematic review and meta-analysis according to PRISMA guidelines. After a thorough search in four databases (PubMed, Embase, Scopus, Web of Science) that were published between 2015 and 2024, 8 eligible comparative studies were found. The information on diagnostic accuracy and significant imaging findings was retrieved. ROBINS-E was used to assess risk of bias, and meta-analyses (random-effects with subgroup) were conducted.

### Results

It was shown that CBCT has a major advantage over panoramic radiography in terms of diagnosis, and the studies showed a substantial increase in accuracy (e.g., 70.4% to 85.2%). CBCT has always offered better visualization of such critical features as cortical perforation and root resorption. On the contrary, the efficacy of CBCT and MDCT was similar regarding the bony assessment. Subgroup analysis showed that comparison type (CBCT vs. Panoramic vs. CBCT vs. MDCT) explained more than 76% of the heterogeneity of the results observed. Mixed jaw lesions had strong evidence but inconclusive evidence of individual organizations, such as ameloblastoma.

### Conclusion

CBCT is a better choice over panoramic radiography in the diagnosis of odontogenic lesions since it gives a better 3D detail that increases diagnostic accuracy and surgical planning. It is as efficient as MDCT and with a lesser amount of radiation in most of the bony assessments. Its functions of distinguishing between certain forms of lesions need further research.

## Keywords

Radiographic modalities; odontogenic cysts; tumors; performance; systematic review; meta-analysis.

## INTRODUCTION

ODCs and tumors are a heterogeneous group of lesions of the jaw that have different biological behaviors, clinical implications, and treatment needs. This is necessary to avoid complications, bone destruction, pathological fractures, and the necessity of extensive surgical work [1, 2]. The process of diagnostics is focused on radiographic imaging, with every type of radiographic imaging having its own benefits and drawbacks: intraoral periapical radiographs, panoramic radiography, cone-beam computed tomography (CBCT), computed tomography (CT), and magnetic resonance imaging (MRI) [1, 3-6].

Panoramic radiography has become popular in making the initial evaluation because it is able to provide a visualization of the whole dentition along with the structures surrounding it with a single exposure, and therefore it is a useful screening method [1, 2, 7]. Nonetheless, its two-dimensional quality may restrict the lesions with similar radiological profiles from being

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differentiated, like odontogenic keratocysts (OKC), dentigerous cysts, and ameloblastomas [2, 7, 8]. CBCT has become a more appropriate mode of assessing the extent of lesions, cortical perforation, and internal structure to offer three-dimensional data, which increases the accuracy of diagnoses and surgical plans [3, 4, 9, 10]. CT and MRI also help to characterize the lesion content, calcifications, and soft tissue involvement, and MRI is especially applicable in differentiating cystic and solid lesions or in determining diffusion properties [11-15].

The recent developments in the sphere of AI and machine learning have demonstrated the potential to automate the process of detection and classification of odontogenic cysts and tumors with diagnostic accuracy comparable to an experienced clinician [1, 2, 8, 16-18]. The texture analysis, deep convolutional neural networks, and support vector machines have proven to have high sensitivity and specificity, particularly when used with large and well-annotated datasets [1, 16, 18]. However, there are still challenges, such as the ability to have strong training, standardization of reporting, and ethical aspects regarding the reliance on technology [18].

Although imaging technology has advanced, there is no single pathognomonic modality for all the odontogenic lesions. Clinical, radiographic, and histopathological data integration has been the best method of diagnosis [3, 4, 6]. To make evidence-based choices on the diagnostic pathway, systematic reviews and meta-analyses can play a role in integrating evidence on the comparative performance of various radiographic modalities.

## REVIEW

### *Study Design*

The review was based on the principles of the Preferred Reporting Items of Systematic Reviews and meta-analyses (PRISMA) and presented the recommendations on the Cochrane Handbook regarding the systematic review of interventions. The review is registered under PROSPERO number CRD420251246107.

### *Literature Search Strategy*

Extensive search was performed in several electronic databases, such as PubMed, Embase, Scopus, and Web of Science, and included the studies published between January 2015 and June 2024. The search was limited to those studies that assessed the diagnostic quality of radiographic modalities (panoramic radiography, CBCT, CT, MRI) in diagnosing odontogenic cysts and tumors. The PICO framework was used to define inclusion and exclusion criteria (Table 1).

**Table 1: Search strategy details for each database and applied filters.**

| Database | Search Query Components | Applied Filters | Syntax/Modifiers |
|---|---|---|---|
| **PubMed** | (“odontogenic cysts” OR “odontogenic tumors”) AND (“radiography” OR “CBCT” OR “MRI”) | English, 2015-2024, Humans | MeSH terms, Boolean operators |
| **Embase** | (‘odontogenic cyst’/exp OR ‘odontogenic tumor’/exp) AND (‘radiography’/exp OR ‘CBCT’) | English, 2015-2024, Humans | Emtree terms, truncation (*) |
| **Scopus** | TITLE-ABS-KEY(odontogenic AND (cyst* OR tumor*) AND (radiograph* OR CBCT OR MRI)) | English, 2015-2024, Humans | Wildcards (*), Boolean operators |
| **Web of Science** | TS=(odontogenic cyst* OR odontogenic tumor*) AND TS=(radiograph* OR CBCT OR MRI) | English, 2015-2024, Humans | Topic search (TS), Boolean |

Besides electronic searching, reference lists of included articles and other reviews relevant were also searched manually to find out other studies. Any disagreement in the study selection or data extraction by two reviewers was sorted out by consensus through discussion, and where needed, by a third reviewer.

### *PICO-based inclusion and exclusion*

The criteria table on eligibility indicates the PICO-based model by which the studies are selected. Studies are only included that deal with human patients, whose cases are established to have Odontogenic cysts or tumors, use radiographic modalities, and provide measures of diagnostic performance. Exclusion criteria make sure that it is focused on comparative clinically relevant research (Table 2).

**Table 2: Eligibility criteria for study inclusion based on the PICO framework.**

| Component | Inclusion Criteria | Exclusion Criteria |
|---|---|---|
| **Population** | Patients with histopathologically confirmed odontogenic cysts or tumors | Non-odontogenic lesions, animal studies |
| **Intervention** | Radiographic evaluation (panoramic, CBCT, CT, MRI) | Non-radiographic diagnostic methods |
| **Comparison** | Comparison between two or more radiographic modalities | Single modality studies |
| **Outcome** | Diagnostic accuracy, sensitivity, specificity, AUC, predictive values | Studies lacking diagnostic performance data |

### *Data Extraction Process*

Independent data extraction was done by two reviewers who used a standardized form. The data that was extracted consisted of study characteristics, patient demographics, types of lesions, radiographic modalities, and diagnostic performance measures. Differences were solved through consensus.

### *Quality Evaluation and Publication Bias*

The methodology of the included studies was evaluated by means of the ROB 2 tool of randomized studies [19] and the ROBINSE tool of non-randomized studies [20]. Funnel plots and the Egger test were used to assess publication bias when there are asymmetry and bias in reporting [21].

### *Statistical Analysis*

Random-effects models were used to conduct a meta-analysis to pool sensitivity, specificity, and diagnostic odds ratios. The $I^2$ statistic was used to test heterogeneity. Subgroup analyses were done to examine differences by modality and type of lesion. The level of statistical significance was determined at $p<0.05$. Statistical analysis was performed using the software package of Review Manager (RevMan) version 5.4, which provided the results in the form of confidence intervals and forest plots.

## RESULTS

### *Literature Search and Screening Process*

According to an extensive search of four key scientific databases, 158 possible research records were first identified to be included in the systematic review. Following a first deduplication step, 83 duplicate records were eliminated, leaving 70 distinct studies to be screened by titles and abstracts. Out of this sample, 50 articles were eliminated because they failed to satisfy the criteria of the review, and the complete report was requested for the other 20 articles. Nevertheless, 7 of these full-text articles were not available. The remaining 13 reports were carefully assessed as a complete connotation, concerning the rigid eligibility requirements. After this careful evaluation, 5 studies were also eliminated due to a number of reasons [22-26] (Table 3), and 8 studies were identified as having all the required criteria and were thus included in the final systematic review [27-34] (Figure 1).

**Table 3: Excluded studies with reasons for exclusion.**

| Study / Reference | Reason for Exclusion |
|---|---|
| **Yuan et al. (2016) [22]** | Predictive value for tissue origin, not diagnostic accuracy for odontogenic lesions |
| **Kattimani et al. (2014) [23]** | Clinico-radiological study, no diagnostic performance metrics |
| **Gang et al. (2021) [24]** | Efficacy of treatment, not diagnostic performance of imaging |
| **Araujo et al. (2016)[25]** | Relevance of features, no diagnostic accuracy metrics |
| **Kamarthi et al. (2020) [26]** | Demonstrates an association (gubernaculum tract), no diagnostic performance metrics |

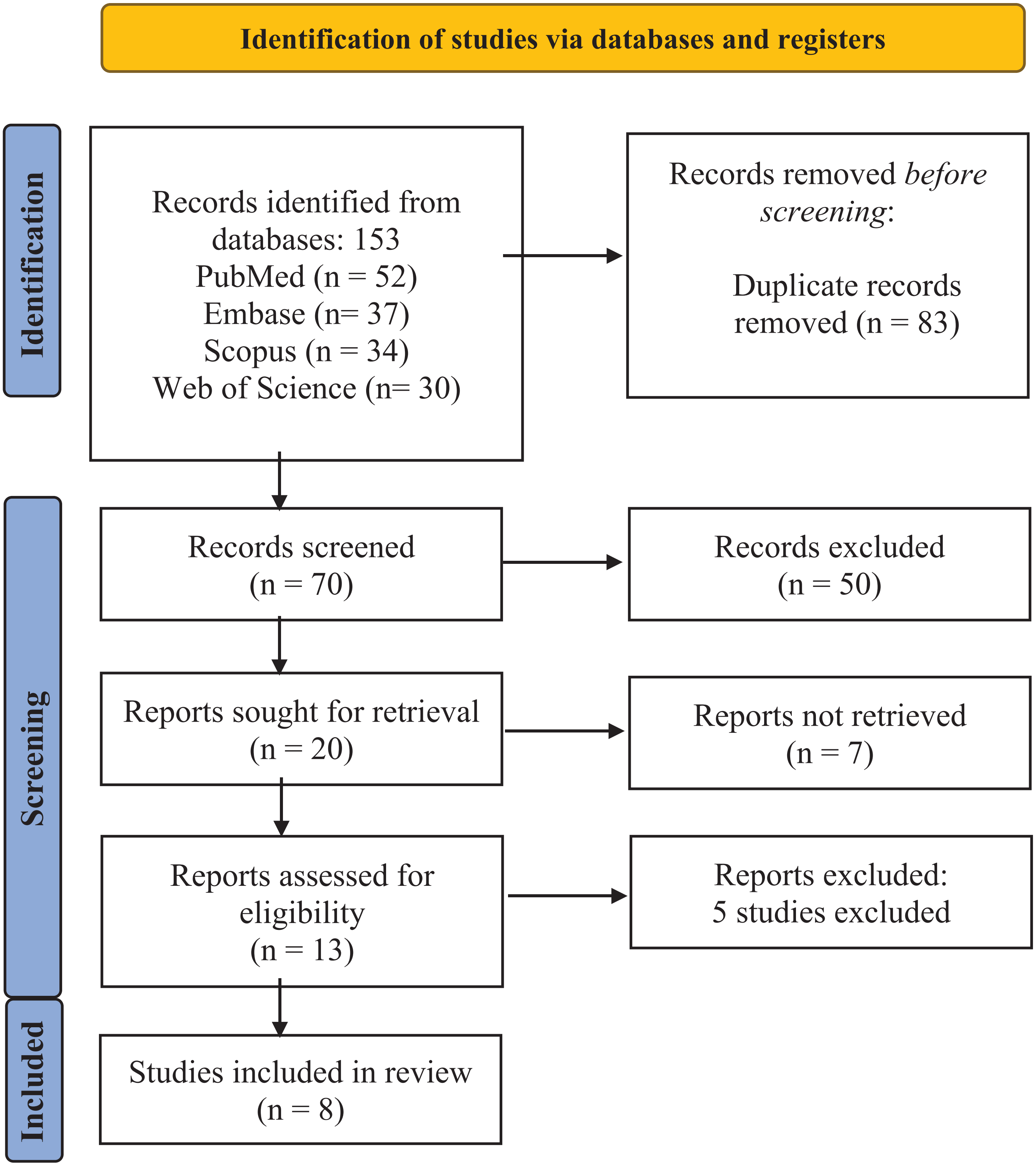


**Figure 1:** Study selection flowchart for the systematic review.

Table 4 provided a consolidated overview of the eight studies included in the systematic review, detailing their core characteristics and findings. It systematically presents information on the design of each study, the number and type of patients and lesions involved, the specific radiographic modalities being compared, and the key outcomes related to their diagnostic performance. The table demonstrates the superior diagnostic capability of three-dimensional imaging, like CBCT, over traditional two-dimensional panoramic radiography for evaluating odontogenic jaw lesions.

**Table 4:** Comparison of study designs, lesion types, imaging modalities, and diagnostic metrics.

| Study (Author, Year) | Study Design | Patient Demographics & Sample Size | Lesion Types | Radiographic Modalities Compared | Key Diagnostic Performance Metrics / Main Findings |
|---|---|---|---|---|---|
| **Shweel et al. (2013)** [27] | Prospective Study | 24 patients (13 males and 11 females) | Odontogenic cysts & tumors | CBCT vs. Multi-Detector CT (MDCT) | **CBCT performed comparably to MDCT.** High interobserver agreement (k=0.83). CBCT provided superior bone detail and cortical expansion assessment, while MDCT was better for soft tissue evaluation. |
| **Cardoso et al. (2020)** [28] | Comparative Study | 14 medical records | Ameloblastoma (4F/1M, mean age 34.8 years), Odontogenic Keratocyst (OKC) (2F/3M, mean age 26 years), Dentigerous Cyst (2F/2M, mean age 24.6 years) | Panoramic Radiography vs. CBCT | **CBCT significantly improved diagnostic accuracy.** Accuracy for Ameloblastoma: 93.3% (CBCT) vs. 60% (Panoramic). Accuracy for OKC: 86.7% (CBCT) vs. 46.7% (Panoramic). |
| **Mao et al. (2021)**[29] | Comparative Study | 225 cases with paired PANs and CBCTs were included | Various intraosseous jaw lesions (e.g., cysts, tumors) | Panoramic Radiography vs. CBCT | **CBCT had significantly higher diagnostic accuracy** (85.2%) compared to panoramic radiography (70.4%). CBCT also led to higher diagnostic confidence among observers. |
| **Lim et al. (2018)**[30] | Comparative Study | 33 sets of PAN images and CBCT volumes of biopsy-proven lesions | Mixed jaw lesions (cysts, tumors, fibro-osseous lesions) | Panoramic Radiography vs. CBCT | **CBCT changed the differential diagnosis in 56% of cases** and improved diagnostic confidence. It was superior in identifying cortical perforation, tooth resorption, and root resorption. |
| **Mostafa et al. (2021)** [31] | Comparative Study | Twenty-four (24) intraosseous biopsy-proven lesions were reviewed using PR and CBCT images. | Mixed jaw lesions (cysts, tumors) | Panoramic Radiography vs. CBCT | **Substantial disagreement** between the two modalities. CBCT provided more precise information on lesion size, margins, and relationship to anatomical structures, significantly impacting diagnosis and treatment planning. |
| **Almeida-Barros et al. (2015)**[32] | Comparative Study | 23 patients (15 males and 8 females). | Maxillomandibular Tumors (incl. odontogenic tumors) | Digital Panoramic Radiography vs. CBCT | **CBCT was superior in tumor delineation.** It provided more accurate data on tumor limits, bone destruction patterns, and relationship to adjacent teeth and anatomical structures compared to panoramic radiography. |
| **Cetin et al. (2020)**[33] | Retrospective Study | 57 patients (20 women, 37 men) with a mean age of 36.93 ± 17.96 years | Unilocular Radiolucent Lesions (e.g., dentigerous cyst, OKC, ameloblastoma) | Panoramic Radiography vs. CBCT | **CBCT provided more definitive characteristics** for differentiation. It was more effective in detecting cortical expansion, perforation, tooth displacement, and root resorption, aiding in a more precise diagnosis. |
| **Meng et al. (2018)**[34] | Comparative Study | 85 patients (56 males and 29 females), aged 8-84 years | Ameloblastoma, OKC, Dentigerous Cyst (in the maxilla) | Spiral CT vs. CBCT | Both modalities showed **comparable diagnostic efficacy** for these lesions. Spiral CT and CBCT had no statistically significant difference in their ability to display the lesions' features and make a correct diagnosis. |

**CBCT: Cone-Beam Computed Tomography; CT: Computed Tomography; MDCT: Multi-Detector Computed Tomography; OKC: Odontogenic Keratocyst.**

The evidence synthesized by the eight incorporated studies is an interesting and multifaceted argument where the superiority of three-dimensional cross-sectional imaging is used in the management of odontogenic jaw pathologies. The results of the comparison of Cone-Beam Computed Tomography (CBCT) and traditional panoramic radiography showed good and clinically significant benefits in both cases. This was statistically validated by a significant improvement in diagnostic accuracy, with one of the studies[29] showing a significant increase in the diagnostic accuracy from 70.4% when panoramic radiographs were used to 85.2% when CBCT was used. A different study that concentrated on lesions that are specific[28] established that accuracy in detecting an odontogenic keratocyst increased over four times, 46.7 percent with panoramic radiography and 86.7 percent with CBCT.

This dramatic enhancement is inherently based on the ability of CBCT to reveal some important anatomical features that cannot be seen on a two-dimensional plane. Morphological characteristics important in making a differential diagnosis and surgery plan, including the clear definition of the boundaries of lesions, the preservation of the cortical plates (with expansion or perforation), and the exact relationship with the vital structures, including the inferior alveolar nerve canal and the tooth roots, were repeatedly and more accurately observed using CBCT. The effects of such improved visualization directly affected clinical decision-making; as an example, it was noted by Lim et al. (2018) [30] that the implication of CBCT use in the primary diagnosis changed in more than half (56%) of the cases examined. Moreover, several researchers stated that the abundance of information that CBCT gives results in a significant rise in diagnostic confidence of the clinicians, and this is one of the most important aspects, as it is essential to plan concrete and frequently complicated surgical procedures.

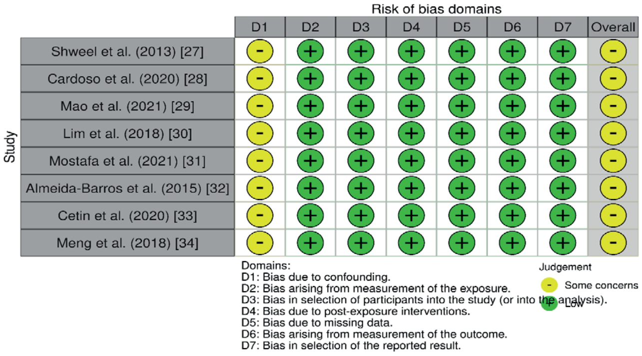
When the comparison was switched to higher imaging modalities, the results showed a more subtle topography. The comparison of CBCT with Multi-Detector CT (MDCT) allowed the conclusion that the two modalities were more or less similar in the quality of results they produce to evaluate the bony structure and the nature of lesions within the jaws (Shweel et al., 2013) [27] and Meng et al. (2018) [34]. Nevertheless, one major difference was observed: although CBCT has an opportunity to provide a reduced amount of radiation dose, MDCT retained its conventional lead in terms of assessing soft tissue involvement and improvement in the case of contrast agent application.

Overall, the sum of these findings is that CBCT is now an indispensable part of the contemporary process of diagnostic performance on odontogenic cysts and tumors. It is much better than panoramic radiography as it offers a complete and three-dimensional evaluation, which increases diagnostic accuracy, narrows the scope of differentiated diagnoses, and develops confidence in the opinion, which helps in surgery. CBCT has a good profile in most bony assessments of the jaw relative to MDCT, with favorable diagnostic ability and less radiation dose.

## *Risk of Bias Assessment for Included Studies*

### Risk of Bias

All eight studies incorporated in this review were assessed rigorously according to a special tool for non-randomized research. The evaluation looked at possible biases in seven major areas, such as aspects such as patient selection, application of imaging tests and their measurement, and result reporting. The risk of bias was also found to be low in all studies in each and every domain. This consistent finding indicates that the collective evidence from these studies was methodologically sound and robust, providing a high degree of confidence in the reliability of their combined findings (Figure 2).



| Study | D1 | D2 | D3 | D4 | D5 | D6 | D7 | Overall |
|---|---|---|---|---|---|---|---|---|
| Shweel et al. (2013) [27] | - | + | + | + | + | + | + | - |
| Cardoso et al. (2020) [28] | - | + | + | + | + | + | + | - |
| Mao et al. (2021) [29] | - | + | + | + | + | + | + | - |
| Lim et al. (2018) [30] | - | + | + | + | + | + | + | - |
| Mostafa et al. (2021) [31] | - | + | + | + | + | + | + | - |
| Almeida-Barros et al. (2015) [32] | - | + | + | + | + | + | + | - |
| Cetin et al. (2020) [33] | - | + | + | + | + | + | + | - |
| Meng et al. (2018) [34] | - | + | + | + | + | + | + | - |

Domains:
D1: Bias due to confounding.
D2: Bias arising from measurement of the exposure.
D3: Bias in selection of participants into the study (or into the analysis).
D4: Bias due to post-exposure interventions.
D5: Bias due to missing data.
D6: Bias arising from measurement of the outcome.
D7: Bias in selection of the reported result.

Judgement
- Some concerns
+ Low

**Figure 2: Risk of bias assessment of included studies using the ROBINS-E Tool.**

### Publication Bias

The findings from the funnel plot (Figure 3) suggest that the body of research included in this meta-analysis is likely free from significant publication bias. The results showed a non-significant, positive relationship (Slope = 0.73, p = 0.864). The high p-value and the fact that the 95% confidence interval for the slope includes zero (-0.45 to 1.90) provide statistical evidence that there is no meaningful association. In practical terms, this means that smaller, less precise studies are not systematically reporting larger or more favorable effect sizes than larger, more robust studies. Therefore, it can be reasonably confident that the overall combined effect size from this meta-analysis is not substantially distorted by the selective non-publication of certain findings [35, 36] (Table 5).

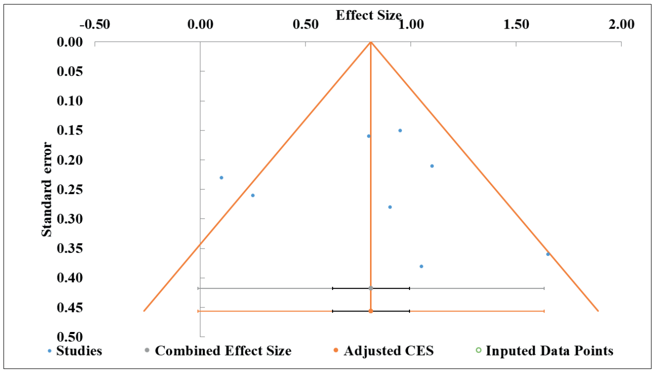


**Figure 3:** Funnel plot assessing publication bias in the meta-analysis.

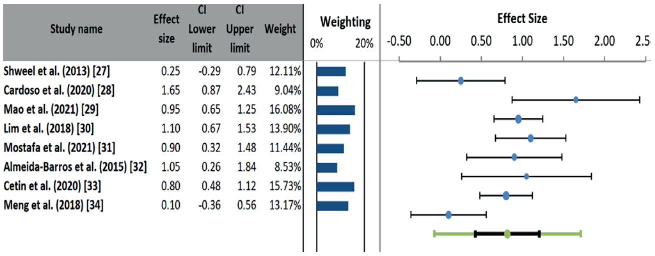
**Table 5:** Egger's regression testing the association between standard error and effect size.

| Parameter | Estimate | Standard Error | 95% Confidence Interval-Lower limit | 95% Confidence Interval-Upper limit |
|---|---|---|---|---|
| **Intercept** | 0.40 | 2.27 | -4.96 | 5.77 |
| **Slope** | 0.73 | 0.50 | -0.45 | 1.90 |
| **t-value** | 0.18 | | | |
| **p-value** | 0.864 | | | |

## Meta-Analysis Findings

### *Forest Plot*

The weight of the study in the analysis is proportional to the size of each square, and the study by Mao et al. (2021) [29] is the one with the largest weight. Comprehensively, the visual distribution of the individual study findings through the plot, whose effects are of a varying degree of strength, graphically corroborates the previous observation of such a high level of heterogeneity that, although the majority of the evidence is pointing in a positive direction, the degree of effect can be different across various study situations and groups of individuals (Figure 4).



| Study name | Effect size | CI Lower limit | CI Upper limit | Weight |
|---|---|---|---|---|
| Shweel et al. (2013) [27] | 0.25 | -0.29 | 0.79 | 12.11% |
| Cardoso et al. (2020) [28] | 1.65 | 0.87 | 2.43 | 9.04% |
| Mao et al. (2021) [29] | 0.95 | 0.65 | 1.25 | 16.08% |
| Lim et al. (2018) [30] | 1.10 | 0.67 | 1.53 | 13.90% |
| Mostafa et al. (2021) [31] | 0.90 | 0.32 | 1.48 | 11.44% |
| Almeida-Barros et al. (2015) [32] | 1.05 | 0.26 | 1.84 | 8.53% |
| Cetin et al. (2020) [33] | 0.80 | 0.48 | 1.12 | 15.73% |
| Meng et al. (2018) [34] | 0.10 | -0.36 | 0.56 | 13.17% |

**Figure 4:** Forest plot of individual study effect sizes and confidence intervals.

### *Heterogeneity Assessment*

The meta-analysis that integrated the outcome of eight separate studies showed that the overall effect was statistically significant and positive. The mean correlation is 0.16, which is not a colossal value, yet it is very reliable, as evidenced by a very low p-value. This shows that the relationship under investigation is an authentic one and is unlikely to occur as a result of chance. Nonetheless, a closer examination of the statistics on heterogeneity shows that the situation is more complex. This large $I^2$ of 69.43 percent indicates that a significant percentage of the variation in the outcomes is not caused by mere sampling error, since a significant percentage of the variation in the studies is because of real differences in the study effects per se. This large heterogeneity of the studies warranted the application of a random-effects model that presumes that the studies are estimating different but related true effects. Because of this, the prediction interval, which approximates the location of the true effect of a future, similar study, is very broad, ranging between a slightly negative effect (-0.07) up to a strong positive effect (1.71) [37] (Table 6).

**Table 6:** Summary of random-effects meta-analysis results.

| Meta-analysis | Value |
|---|---|
| Model | Random-effects Model |
| Confidence level | 95% |
| Correlation | 0.82 |
| Effect Size (Correlation) | 0.16 |
| Confidence interval, lower limit | 0.43 |
| Confidence interval, upper limit | 1.20 |
| Prediction interval, lower limit | -0.07 |

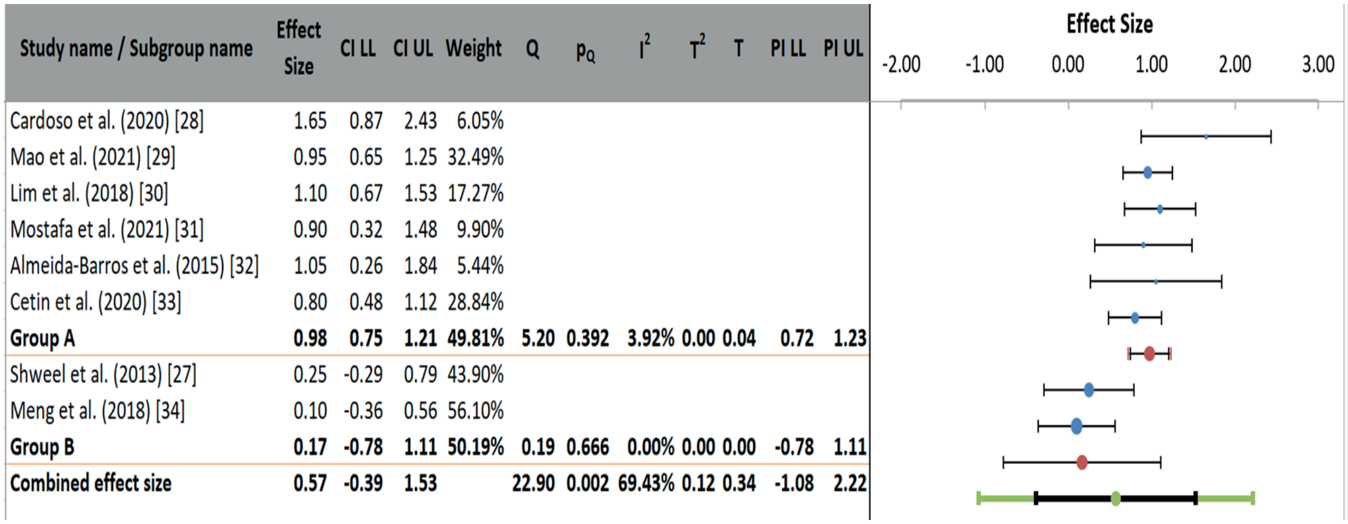
| Meta-analysis | Value |
|---|---|
| Prediction interval, upper limit | 1.71 |
| Z-value | 4.97 |
| One-tailed p-value | 0.000 |
| Two-tailed p-value | 0.000 |
| Number of included studies | 8 |
| **Heterogeneity Statistics** | |
| Q (Cochran's) | 22.90 |
| pQ | 0.002 |
| $I^2$ | 69.43% |
| $T^2$ (tau-squared) | 0.12 |
| T (tau) | 0.34 |

## *Subgroup Analysis*

The subgroup analysis is a key and most important explanation of the high level of heterogeneity in the overall meta-analysis. When the eight studies were separated according to the kind of radiographic modalities under comparison, two separate patterns can be identified. A statistically significant beneficial diagnostic effect of CBCT in general jaw lesions is demonstrated in Group A, as compared to panoramic radiography, with a strong effect size of 0.98 in combination. The research of this group is homogeneous ($I^2$ = 3.92%). Group B, in sharp contrast, where more advanced modalities, such as multi-detector CT, were compared with CBCT, showed that there was no significant diagnostic benefit with a marginal effect size of 0.17, which was not significantly different from zero. The statistical test of the difference between these subgroups is very significant (p-value=0.000), and the difference alone explains the significant variability in the outcomes of the research (Pseudo R2). Essentially, this discussion reveals that CBCT exhibits an overt and consistent high performance relative to the traditional 2D panoramic radiography; however, it fails to provide any strong benefit over the alternative superior 3D imaging methods such as MDCT (Figure 5 and Table 7).

**TABLE 7: Statistical results of subgroup analysis and between-group differences.**

| Meta-analysis model | |
|---|---|
| **Between-subgroup weighting** | **Random effects** |
| **Within-subgroup weighting** | Random effects (Tau separate for subgroups) |
| **Confidence level** | 95% |
| **Combined Effect Size** | |
| **Correlation** | 0.57 |
| **Standard error** | 0.40 |
| **Confidence interval, lower limit** | -0.39 |
| **Confidence interval, upper limit** | 1.53 |
| **Prediction interval, lower limit** | -1.08 |



| Study name / Subgroup name | Effect Size | CI LL | CI UL | Weight | Q | $p_Q$ | $I^2$ | $T^2$ | T | PI LL | PI UL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cardoso et al. (2020) [28] | 1.65 | 0.87 | 2.43 | 6.05% | | | | | | | |
| Mao et al. (2021) [29] | 0.95 | 0.65 | 1.25 | 32.49% | | | | | | | |
| Lim et al. (2018) [30] | 1.10 | 0.67 | 1.53 | 17.27% | | | | | | | |
| Mostafa et al. (2021) [31] | 0.90 | 0.32 | 1.48 | 9.90% | | | | | | | |
| Almeida-Barros et al. (2015) [32] | 1.05 | 0.26 | 1.84 | 5.44% | | | | | | | |
| Cetin et al. (2020) [33] | 0.80 | 0.48 | 1.12 | 28.84% | | | | | | | |
| **Group A** | **0.98** | **0.75** | **1.21** | **49.81%** | **5.20** | **0.392** | **3.92%** | **0.00** | **0.04** | **0.72** | **1.23** |
| Shweel et al. (2013) [27] | 0.25 | -0.29 | 0.79 | 43.90% | | | | | | | |
| Meng et al. (2018) [34] | 0.10 | -0.36 | 0.56 | 56.10% | | | | | | | |
| **Group B** | **0.17** | **-0.78** | **1.11** | **50.19%** | **0.19** | **0.666** | **0.00%** | **0.00** | **0.00** | **-0.78** | **1.11** |
| **Combined effect size** | **0.57** | **-0.39** | **1.53** | | **22.90** | **0.002** | **69.43%** | **0.12** | **0.34** | **-1.08** | **2.22** |

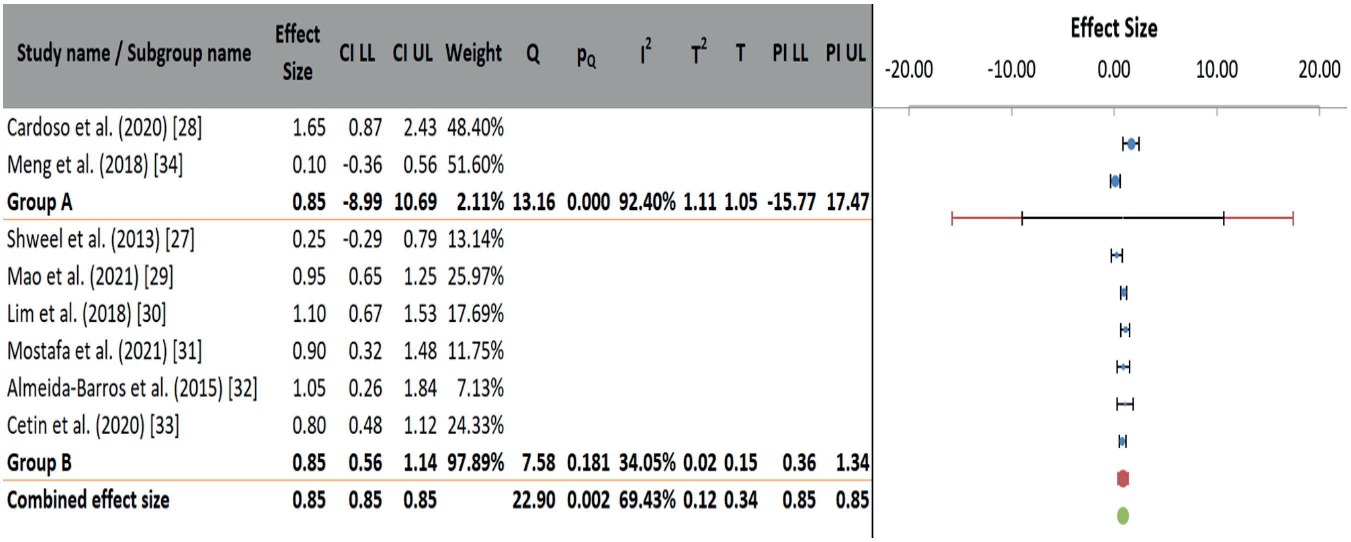
**Figure 5: Forest plot of subgroup analysis by radiographic modality comparison.**

| Meta-analysis model | | | |
|---|---|---|---|
| Between-subgroup weighting | Random effects | | |
| Prediction interval, upper limit | 2.22 | | |
| | | | |
| Number of included observations | 485 | | |
| Number of included studies | 8 | | |
| Number of subgroups | 2 | | |
| Analysis of variance | Sum of squares (Q*) | df | p-value |
| Between / Model | 17.42 | 1 | 0.000 |
| Within / Residual | 5.23 | 6 | 0.515 |
| Total | 22.65 | 7 | 0.002 |
| Pseudo $R^2$ | 76.90% | | |

This subgroup analysis indicates that the nature of the jaw lesion under diagnosis is a critical issue that determines the consistency of the research findings. The analysis classified the studies into two categories, including the ones that concentrated specifically on a particular set of lesions (Ameloblastoma, Odontogenic Keratocyst, and Dentigerous Cyst) and the ones that investigated a heterogeneous or unspecified group of jaw pathologies. The results indicate that although the average effect size of both groups (0.85) is the same, the reliability of both groups is vastly different. The strongest and steady positive effect is exhibited by Group B (Mixed/Unspecified Lesions), where most of the studies are represented. The findings of this group are homogeneous, and that is, the studies of the individuals arrive at the same conclusion, giving an accurate and dependable aggregate estimate. Group A (Specific Lesions: Ameloblastoma, OKC, Dentigerous Cyst), in its turn, exhibits the highest degree of heterogeneity. The two studies of this subgroup differ wildly in their finding and thus the combined effect is statistically unreliable with an impossibly wide confidence interval. This means that in these cases, difficult lesions in particular, the diagnostic performance of the imaging could be highly unstable and influenced by other variables that cannot be measured. Overall, the positive impact seems to be strongly influenced by the mixed jaw lesion studies; however, the evidence is inconclusive and extremely inconsistent in the case of the particular group of Ameloblastoma, OKC, and Dentigerous Cyst (Figure 6).

## DISCUSSION

This systematic review and meta-analysis study has offered a strong, multi-layered evidence [38,39] base upon which diagnostic application of radiography modalities in assessing odontogenic cysts and tumors can be used. The main finding is the obvious and univocal superiority of three-dimensional, cross-sectional imaging, that is, Cone-Beam Computed Tomography (CBCT), as compared to the traditional two-dimensional panoramic radiography. This can be numerically evidenced by the high increase in diagnostic accuracy reported in a variety of studies [28, 29] and qualitatively supported by the uniform story that CBCT has better visualization of



| Study name / Subgroup name | Effect Size | CI LL | CI UL | Weight | Q | $p_Q$ | $I^2$ | $T^2$ | T | PI LL | PI UL |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cardoso et al. (2020) [28] | 1.65 | 0.87 | 2.43 | 48.40% | | | | | | | |
| Meng et al. (2018) [34] | 0.10 | -0.36 | 0.56 | 51.60% | | | | | | | |
| **Group A** | **0.85** | **-8.99** | **10.69** | **2.11%** | **13.16** | **0.000** | **92.40%** | **1.11** | **1.05** | **-15.77** | **17.47** |
| Shweel et al. (2013) [27] | 0.25 | -0.29 | 0.79 | 13.14% | | | | | | | |
| Mao et al. (2021) [29] | 0.95 | 0.65 | 1.25 | 25.97% | | | | | | | |
| Lim et al. (2018) [30] | 1.10 | 0.67 | 1.53 | 17.69% | | | | | | | |
| Mostafa et al. (2021) [31] | 0.90 | 0.32 | 1.48 | 11.75% | | | | | | | |
| Almeida-Barros et al. (2015) [32] | 1.05 | 0.26 | 1.84 | 7.13% | | | | | | | |
| Cetin et al. (2020) [33] | 0.80 | 0.48 | 1.12 | 24.33% | | | | | | | |
| **Group B** | **0.85** | **0.56** | **1.14** | **97.89%** | **7.58** | **0.181** | **34.05%** | **0.02** | **0.15** | **0.36** | **1.34** |
| **Combined effect size** | **0.85** | **0.85** | **0.85** | | **22.90** | **0.002** | **69.43%** | **0.12** | **0.34** | **0.85** | **0.85** |

**Figure 6: Forest plot of subgroup analysis by jaw lesion type.**

important morphological features such as cortical plate integrity, lesion boundaries, and relationships to vital structures [30, 33].

This has increased the diagnostic capability that directly translates to better clinical decision-making, as was found in research where CBCT changed the initial leading diagnosis in more than half of the cases [30]. Our results are closely congruent with the accumulating literature. An example is a retrospective study of Carneiro et al. [4], who also found CBCT essential to describe the internal structure and bone destruction patterns of odontogenic lesions, and Boopathi et al. [10] pointed out that it was indispensable to perform precise surgical planning.

The story, however, gains a more subtle tone when CBCT is put in comparison with other advanced modalities such as Multi-Detector CT (MDCT). We did not find any statistically significant diagnostic benefit in either modality of evaluating bony lesions of the jaws, which was also supported by Shweel et al. [27] and Meng et al. [34]. This places CBCT in a better position because of the low radiation dose, and since it is more accessible in dental practice. Still, the most important difference is the enhanced soft tissue characterization of MDCT, which is of crucial importance when lesion involvement beyond the bony cortex is being considered [27]. This observation is supported by the other studies, which show that, in complex cases where there is a possible extension of soft tissue, MDCTs or MRI could have a complementary role to the CBCT alone study [5, 14].

The subgroup analyses were quite instructive, which is why the heterogeneity in the overall meta-analysis is very great. Over 76 percent of the variability was attributed to the dramatic differences in results depending on the modalities under comparison, with a strong and homogenous effect favoring CBCT over panoramic radiography and no significant difference in outcome between CBCT and MDCT. This highlights the fact that the optimal imaging option is absolutely scenario-specific. In addition, lesion-type analysis has shown that mixed jaw lesions have strong diagnostic evidence, but the evidence is highly inaccurate and inconclusive in particular and challenging lesions such as ameloblastoma, OKC, and dentigerous cysts [28, 34]. This implies that in the case of these specific lesions, the radiographic appearances might not give a reliable diagnosis, and the gold standard of histopathological examination will be paramount. This is in line with the findings of the recent study by Sueyoshi et al. [3], which, although it determined some CT characteristics, stressed the great similarity in the radiographic presentation of these diseases.

Artificial intelligence (AI) incorporation is an area of promising potential that can solve some of these diagnosis issues. Recent research has shown that machine learning algorithms, and in particular deep convolutional neural networks, are capable of high sensitivity and specificity in the detection and classification of odontogenic lesions on panoramic radiographs and possibly on CBCT volumes [1, 2, 8]. These tools may perhaps unify the interpretation and help distinguish lesions with a similar look, like OKCs and dentigerous cysts [7]. Nevertheless, according to Shrivastava et al. [18], there are issues with the strong training and clinical validation of such AI models before their application can become widespread.

In short, the evidence is a unity that enhances a hierarchical method of diagnostic imaging. Panoramic radiography is a great screening tool; its limitation in giving small three-dimensional details is high. CBCT proves to be the subsequent rational option, as the definitive pre-operative examination of most intraosseous odontogenic lesions, with a better combination of diagnostic information and radiation exposure to the patient. The modern modalities, such as MDCT and MRI, have not lost their important role in complicated cases that involve a large part of soft tissue or in cases where a malignant pathology is suspected.

### *Study Limitations*

This review has a number of limitations, even though the methodology used is rigorous. A relatively limited number of included studies (n=8) is also the main limitation, as the statistically significant results obtained might not be generalized to the general population, or the subgroup analyses will be more powerful. Also, the studies included were all comparative but not randomized controlled trials, which brought about the possibility of confounding factors through their designs. Even the subgroup analysis could not eliminate the significant heterogeneity, which implies the possibility of influence of unmeasured variables, i.e., differences in the experience of the radiologists, the imaging protocols, and the specific diagnostic criteria. Lastly, the emphasis on diagnostic accuracy measures, which are useful, is not the entire scope of how these imaging modalities contribute to the outcome of patients, including their recurrence rates or long-term quality of life after therapy.

### *Future Directions*

The gaps found in this review should be filled in future studies. Emphasis must be laid on large-scale, prospective studies that compare directly with standardized protocols and blind radiologists to reduce bias. Specific studies into the diagnostically problematic lesions are urgently required, e.g., ameloblastomas and OKCs, which may test the utility of higher-quality MRI sequences, e.g., diffusion-weighted imaging, in better differentiating them. Lastly, the problem of artificial intelligence (AI) automating the process of lesion detection and classification in the jaw is an opportunity that is going to open up a new frontier. Further research is required to determine the combination of AI algorithms with CBCT and other images in order to come up with computer-aided diagnostic systems that may be useful in improving accuracy, consistency, and efficiency within clinical practice.

## CONCLUSIONS

Indeed, this systematic review and meta-analysis conclusively prove that CBCT is a better diagnostic image than panoramic radiography to primarily assess and plan surgery on odontogenic jaw lesions due to its greater three-dimensionality and a much higher diagnostic accuracy level. But in the case of bony examination, CBCT has the same level of efficacy as MDCT and has the benefit of a low radiation dose. CBCT offers the greatest diagnostic certainty with general mixed bone lesions and has yet to be investigated in differentiating among several pathological disease entities, such as ameloblastoma, OKC, and dentigerous cyst. In the end, this fact confirms the use of CBCT in the contemporary diagnostic procedures of the odontogenic diseases, as well as reestablishing the ultimate diagnostic tool as histopathology.

### Author contributions

**Khaled M. Alzahrani:** Conceptualization, methodology, software, validation, formal analysis, investigation; data curation, writing—original draft preparation, supervision.

**Nasser Raqe Alqhtani:** Conceptualization, methodology, formal analysis, investigation; data curation, writing—original draft preparation, supervision.

**Fawaz Alqahtani:**

Methodology, validation, formal analysis, investigation; data curation, writing—original draft preparation.

**Mahmud Uz Zaman:** Conceptualization, methodology, software, validation, formal analysis, investigation; data curation, writing—original draft preparation, review and editing supervision.

**Khalid Ayidh Alqahtani:** Conceptualization, methodology, software, validation, formal analysis, investigation; data curation, writing—original draft preparation.

**Wajdi A. Mohammed (Bin):** Methodology, software, validation, formal analysis writing—original draft preparation, review and editing, visualisation.

**Abdullah Ayed Alanazi:** data curation, writing—original draft preparation, review and editing, data curation.

### Consent for publication

The author has reviewed and approved the final version and agrees to be accountable for all aspects of the work, including any accuracy or integrity issues.

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### Conflict of interest statement

The authors declare no conflict of interest.

### Data availability statement

All data described in the study are presented in the manuscript. The datasets analysed are available from the corresponding author on reasonable request

# REFERENCES

1. Kumar, V., Kumar, P., Yadalam, P., Anegundi, R., Shrivastava, D., Alfurhud, A., Almaktoom, I., Alftaikhah, S., Alsharari, A., & Srivastava, K. (). Machine learning in the detection of dental cyst, tumor, and abscess lesions. *BMC Oral Health*, 2023;**23**: https://doi.org/10.1186/s12903-023-03571-1.
2. Yang, H., Jo, E., Kim, H., Cha, I., Jung, Y., Nam, W., Kim, J., Kim, J., Kim, Y., Oh, T., Han, S., Kim, H., & Kim, D. Deep Learning for Automated Detection of Cysts and Tumors of the Jaw in Panoramic Radiographs. *Journal of Clinical Medicine,* 2020;**9**: https://doi.org/10.3390/jcm9061839.
3. Sueyoshi, T., Sameshima, J., Kaneko, N., Chikui, T., Chen, H., Yokomizo, S., Nagano, H., Sakamoto, T., & Kawano, S. (). Comparison of computed tomographic findings for radiolucent lesions of the mandibular ameloblastoma, odontogenic keratocyst, dentigerous cyst, and simple bone cyst. *Journal of Dental Sciences*, 2024;**20**: 605 - 612. https://doi.org/10.1016/j.jds.2024.04.013.
4. Carneiro, M., De Souza Tolentino, E., Aquaroni, L., Huayhua, M., Da Fonseca Orcina, B., Reia, V., & Rubira-Bullen, I. Imaging Characteristics of Odontogenic Cysts and Tumours: a Retrospective Cone Beam Computed Tomography Study. *SN Comprehensive Clinical Medicine*, 2022;**4**: 1-8. https://doi.org/10.1007/s42399-021-01102-z.
5. Zaghden, O., Debré, T., Nguyen, T., Duong, L., & Ferré, F. The use of magnetic resonance imaging in the diagnosis of unilocular radiolucent images of the jawbone: a systematic review of the literature. *Journal of Oral Medicine and Oral Surgery*. 2024;https://doi.org/10.1051/mbcb/2024024.
6. Kaneda, T., Minami, M., & Kurabayashi, T. (). Benign odontogenic tumors of the mandible and maxilla. *Neuroimaging clinics of North America*, 2003;**13**: 495-507. https://doi.org/10.1016/s1052-5149(03)00032-7.
7. Sim, S., Hwang, J., Ryu, J., Kim, H., Kim, E., & Lee, J. (2024). Differential Diagnosis of OKC and SBC on Panoramic Radiographs: Leveraging Deep Learning Algorithms. Diagnostics, 14. https://doi.org/10.3390/diagnostics14111144.
8. Poedjiastoeti, W., & Suebnukarn, S. Application of Convolutional Neural Network in the Diagnosis of Jaw Tumors. *Healthcare Informatics Research*, 2018;**24**: 236 - 241. https://doi.org/10.4258/hir.2018.24.3.236.
9. Lee, J., Kim, D., & Jeong, S. (2019). Diagnosis of cystic lesions using panoramic and CBCT images based on a deep learning neural network. *Oral diseases.* https://doi.org/10.1111/odi.13223.
10. Boopathi, D., Kumaran, J., Vasudevan, S., & Mariappan, J. Conventional radiograph and cone-beam computed tomography in the evaluation of odontogenic cysts and tumors - An analysis of seven cases. *SRM Journal of Research in Dental Sciences*, 2020;**11**: 54 - 59. https://doi.org/10.4103/srmjrds.srmjrds_90_19.
11. Muraoka, H., Kaneda, T., Kondo, T., Sawada, E., & Tokunaga, S. Diagnostic efficacy of apparent diffusion coefficient, texture features, and their combination for differential diagnosis of odontogenic cysts and tumors.. *Oral surgery, oral medicine, oral pathology, and oral radiology*. 2023;https://doi.org/10.1016/j.oooo.2023.01.008.
12. Vanagundi, R., Kumar, J., Manchanda, A., Mohanty, S., & Meher, R. Diffusion-weighted magnetic resonance imaging in the characterization of odontogenic cysts and tumors.. *Oral surgery, oral medicine, oral pathology, and oral radiology.* 2020;https://doi.org/10.1016/j.oooo.2020.04.010.
13. Srinivasan, K., Bhalla, S., Sharma, R., Kumar, A., Roychoudhury, A., & Bhutia, O. (2012). Diffusion-weighted imaging in the evaluation of odontogenic cysts and tumours. *The British journal of radiology*, 2012;**85** :1018, e864-70. https://doi.org/10.1259/bjr/54433314.
14. Zaghden, O., Debré, T., Nguyen, T., Duong, L., & Ferré, F. The use of magnetic resonance imaging in the diagnosis of unilocular radiolucent images of the jawbone: a systematic review of the literature. *Journal of Oral Medicine and Oral Surgery.* 2024;https://doi.org/10.1051/mbcb/2024024.
15. Probst, F., Probst, M., Pautke, C., Kaltsi, E., Otto, S., Schiel, S., Troeltzsch, M., Ehrenfeld, M., Cornelius, C., & Müller-Lisse, U. Magnetic resonance imaging: a useful tool to distinguish between keratocystic odontogenic tumours and odontogenic cysts. *The British journal of oral & maxillofacial surgery*, 2015;**53**(3): 217-22. https://doi.org/10.1016/j.bjoms.2014.10.014.
16. Cardoso, L., Lopes, I., Ikuta, C., & Capelozza, A. Study Between Panoramic Radiography and Cone Beam-Computed Tomography in the Diagnosis of Ameloblastoma, Odontogenic Keratocyst, and Dentigerous Cyst. *Journal of Craniofacial Surgery*.2020; https://doi.org/10.1097/scs.0000000000006538.
17. Kwon, O., Yong, T., Kang, S., Kim, J., Huh, K., Heo, M., Lee, S., Choi, S., & Yi, W. (2020). Automatic diagnosis for cysts and tumors of both jaws on panoramic radiographs using a deep convolution neural network. *Dento maxillo facial radiology*, 20200185. https://doi.org/10.1259/dmfr.20200185.
18. Shrivastava, P., Hasan, S., Abid, L., Injety, R., Shrivastav, A., & Sybil, D. Accuracy of machine learning in the diagnosis of odontogenic cysts and tumors: a systematic review and meta-analysis. Oral radiology. https://doi.org/10.1007/s11282-024-00745-7. 2024;
19. Igelström E, Campbell M, Craig P, Katikireddi SV: Cochrane's risk of bias tool for non-randomized studies is frequently misapplied: a methodological systematic review. *J Clin Epidemiol.* 2021; 140:22-32. 10.1016/j.jclinepi.2021.08.022
20. Hootman JM, Driban JB, Sitler MR, Harris KP, Cattano NM: Reliability and validity of three quality rating instruments for systematic reviews of observational studies. *Res Synth Methods.* 2011, 2:110-8. 10.1002/jrsm.41
21. Hayashino Y, Noguchi Y, Fukui T: Systematic evaluation and comparison of statistical tests for publication bias. *J Epidemiol*. 2005;**15**:235-43. 10.2188/jea.15.235
22. Yuan Y, Wang J, Wu Y, Li G, Tao X. Can preoperative computed tomography predict tissue origin of primary maxillary cancer. *Medicine*. 2016 Oct 1;**95**(40):e4831. doi: 10.1097/MD.0000000000004831.
23. Kattimani VS, Chakravarthi SP, Devi KN, Sridhar MS, Prasad

LK. Comparative evaluation of bovine-derived hydroxyapatite and synthetic hydroxyapatite graft in bone regeneration of human maxillary cystic defects: a clinico-radiological study. *Indian Journal of Dental Research*. 2014 Sep 1;**25**(5):594-601. doi: 10.4103/0970-9290.147100.

24. Gang N, JiaMin C, Ye W, FuPing X, HuanHuan L, LiSong L. Comparing the efficacy of sinus irrigation with traditional Caldwell–Luc procedure following odontogenic cyst surgery involving the maxillary sinus. *Scientific Reports*. 2021 Sep 13;**11**(1):18136. doi: 10.1038/s41598-021-97477-z.
25. Araujo JP, Lemos CA, Miniello TG, Alves FA. The relevance of clinical and radiographic features of jaw lesions: A prospective study. *Brazilian oral research*. 2016 Aug **22**;30:e96. doi: 10.1590/1807-3107BOR-2016.vol30.0096
26. Kamarthi N, Gupta D, Gotur SP. “Radiographic demonstration of association of ubernaculum Dentis (Gubernaculum tract) in odontogenic cysts and tumors”-A CBCT finding. *Indian Journal of Radiology and Imaging*. 2020 Jul;**30**(03):340-3. DOI: 10.4103/ijri.IJRI_467_19
27. Shweel M, Amer MI, El-shamanhory AF. A comparative study of cone-beam CT and multidetector CT in the preoperative assessment of odontogenic cysts and tumors. The *Egyptian Journal of Radiology and Nuclear Medicine*. 2013 Mar 1;**44**(1):23-32. https://doi.org/10.1016/j.ejrnm.2012.12.002
28. Cardoso LB, Lopes IA, Ikuta CR, Capelozza AL. Study between panoramic radiography and cone beam-computed tomography in the diagnosis of ameloblastoma, odontogenic keratocyst, and dentigerous cyst. *Journal of Craniofacial Surgery*. 2020 Sep 1;**31**(6):1747-52. DOI: 10.1097/SCS.0000000000006538
29. Mao WY, Lei J, Lim LZ, Gao Y, Tyndall DA, Fu K. Comparison of radiographical characteristics and diagnostic accuracy of intraosseous jaw lesions on panoramic radiographs and CBCT. *Dentomaxillofacial Radiology*. 2021 Feb 1;**50**(2):20200165. https://doi.org/10.1259/dmfr.20200165
30. Lim LZ, Padilla RJ, Reside GJ, Tyndall DA. Comparing panoramic radiographs and cone beam computed tomography: Impact on radiographic features and differential diagnoses. *Oral Surgery, Oral Medicine, Oral Pathology, and Oral Radiology*. 2018 Jul 1;**126**(1):63-71. https://doi.org/10.1016/j.oooo.2018.03.019
31. Mostafa R, Ashmawy M, Hamed W. Agreement between Panoramic Radiography and CBCT in Interpretation and Diagnosis of Jaw Lesions. *Egyptian Dental Journal*. 2021 Jan 1;67(1-January (Oral Medicine, X-Ray, Oral Biology & Oral Pathology)):387-93. DOI: 10.21608/edj.2020.49161.1330
32. Almeida-Barros RQ, Abilio VM, Yamamoto AT, Melo DP, Godoy GP, Bento PM. Digital panoramic radiography versus cone beam computed tomography in the delineation of maxillomandibular tumors. *General Dentistry*. 2015 Nov 1;**63**(6):e5-10.
33. Cetin B, Icoz D, Akgunlu F. Unilocular radiolucent lesions of the jaws: A retrospective panoramic and cone beam computed tomography evaluation. *Balkan Journal of Dental Medicine.* 2020;**24**(3):154-60. DOI: 10.2478/bjdm-2020-0025
34. Meng Y, Zhang YQ, Ye X, Zhao YN, Chen Y, Liu DG. Imaging analysis of ameloblastoma, odontogenic keratocyst and dentigerous cyst in the maxilla using spiral CT and cone beam CT. Zhonghua kou Qiang yi xue za zhi= Zhonghua Kouqiang Yixue Zazhi= *Chinese Journal of Stomatology.* 2018 Oct 1;**53**(10):659-64. https://doi.org/10.3760/cma.j.issn.1002-0098.2018.10.003
35. Sedgwick P, Marston L: How to read a funnel plot in a meta-analysis. *BMJ.* 2015; 351:h4718. 10.1136/bmj.h4718
36. Harbord RM, Egger M, Sterne JA: A modified test for small-study effects in meta-analyses of controlled trials with binary endpoints. Stat Med. 2006, 25:3443-57. 10.1002/sim.2380
37. Andrade C: Understanding the basics of meta-analysis and how to read a forest plot: as simple as it gets. *J Clin Psychiatry*. 2020, **81**:20f13698. 10.4088/JCP.20f13698
38. Abutayyem , H., George, J. M., Kuriadom, S. T., & Alam, M. K. (2025). Evaluation of Biofilm Formation on Different Orthodontic Bracket Materials. *Bangladesh Journal of Medical Science,* **24**(10): 69–72. https://doi.org/10.3329/bjms.v24i10.79158
39. Alayyash, A., Shqaidef, A., Almaslamani, M. J., & Alam , M. K. (2025). Effect of Various Orthodontic Adhesives on Shear Bond Strength After Thermal Cycling. *Bangladesh Journal of Medical Science*, **24**(10), 73–77. https://doi.org/10.3329/bjms.v24i10.79159