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Original article

Clinical Diagnostic Performance of Panoramic Radiography and the Complementary Role of Cone Beam Computed Tomography in Maxillary Sinus Pathology

Ibtisam Senussi[1]*, Antisar Ben Amer[1], Aya Krayem[1], Salem Elgelaib[2]

[1]*Department of Oral Medicine and Oral Pathology, Faculty of Dentistry, Misurata University, Misurata, Libya*
[2]*Department of Periodontics and Oral Biology, Faculty of Dentistry, Misurata University, Misurata, Libya*
Corresponding Email. *ibriek@yahoo.com*

Abstract
The maxillary sinus is closely related to the posterior maxillary teeth, making accurate radiographic evaluation essential for diagnosing odontogenic and non-odontogenic sinus pathologies and guiding appropriate treatment planning. This study aimed to evaluate the diagnostic performance of panoramic radiography (OPG) compared with cone beam computed tomography (CBCT) and to identify the maxillary sinus lesions that can be reliably detected on panoramic imaging. A retrospective cross-sectional study was conducted using 437 panoramic radiographs obtained from patients attending public dental clinics in Misurata, Libya. Among these, 316 patients underwent CBCT on the same day, allowing direct paired comparison between imaging modalities. CBCT served as the reference standard. Evaluated pathologies included mucosal thickening, odontogenic and non-odontogenic sinusitis, mucous retention cysts, mucosal polyps, foreign bodies, mucoceles, oroantral fistulas, fluid accumulation, and tumors. Statistical analysis was performed using the chi-square test and McNemar's test, with statistical significance set at $P < 0.05$. Mucosal thickening was the most common finding (26%), followed by non-odontogenic sinusitis (18%), odontogenic sinusitis (13%), mucosal polyps (10%), mucous retention cysts (8%), and foreign bodies (2%). OPG detection varied significantly according to lesion type ($\chi^2 = 71.38$, $P < 0.001$). Compared with CBCT, panoramic radiography demonstrated significantly lower sensitivity for subtle inflammatory lesions, whereas well-defined lesions, including mucous retention cysts and mucosal polyps, were reliably identified. CBCT provided superior assessment of lesion morphology, disease extent, and tooth–sinus anatomical relationships. Panoramic radiography remains a valuable, accessible first-line imaging modality for the initial evaluation of maxillary sinus pathology. However, CBCT should be considered when subtle inflammatory disease, odontogenic extension, or detailed anatomical assessment is required. A stepwise imaging approach integrating both modalities may improve diagnostic accuracy and clinical decision-making.
Keywords: Cone-Beam Computed Tomography, Panoramic Radiography, Maxillary Sinus, Diagnostic Imaging.

Introduction

The maxillary sinus is the largest paranasal sinus and represents an important anatomical structure within the maxillofacial complex. Its close anatomical relationship with the roots of the posterior maxillary teeth makes it highly relevant in dental diagnosis and treatment planning [1-3]. The close anatomical relationship between the maxillary sinus floor and the roots of the posterior maxillary teeth may contribute to complications such as oroantral communication during tooth extraction, implant placement, and other surgical procedures [4]. Furthermore, odontogenic infections originating from posterior maxillary teeth may extend into the maxillary sinus because of the close anatomical relationship between the dental roots and the sinus floor, contributing to pathological conditions such as mucosal thickening, sinusitis, retention cysts, and polyps [5,6]. Approximately 10–12% of maxillary sinusitis cases are considered odontogenic in origin, highlighting the importance of early diagnosis and accurate radiographic assessment [7,8].

Radiographic evaluation of the maxillary sinus is therefore essential for diagnosis, treatment planning, and surgical risk assessment. Conventional imaging modalities, including periapical radiographs, Waters view, and orthopantomography (OPG), are commonly used because of their accessibility, low radiation dose, and cost-effectiveness [9-11]. However, panoramic radiography has several inherent limitations. As a two-dimensional imaging modality, OPG is affected by image distortion, magnification errors, superimposition of anatomical structures, and limited spatial resolution, all of which may compromise diagnostic accuracy, particularly in subtle or complex sinus pathologies [9,12-14]. In addition, panoramic radiography demonstrates limited capability in evaluating buccolingual dimensions and accurately determining the relationship between posterior maxillary tooth roots and the maxillary sinus floor [15-18].

Cone beam computed tomography (CBCT) has significantly improved maxillofacial imaging by providing high-resolution three-dimensional visualization without anatomical superimposition [12,19]. CBCT enables accurate assessment of sinus anatomy, mucosal alterations, lesion extent, and tooth–sinus relationships, thereby improving diagnostic accuracy and surgical planning [13,15,20]. Previous studies have demonstrated that CBCT is superior to panoramic radiography in detecting sinus membrane thickening, odontogenic sinusitis, cystic lesions, anatomical variations, and incidental maxillary sinus pathologies [20,21]. Because of the increasing recognition of odontogenic maxillary sinus disease and the diagnostic

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limitations associated with conventional radiography, understanding the diagnostic performance of panoramic imaging compared with CBCT has become clinically important [22-24]. Several studies have directly compared OPG with CBCT and reported that panoramic radiography has limited sensitivity in detecting sinus membrane thickening, sinus septa, oroantral communication, and root intrusion into the maxillary sinus [11,16-18,25-27,31]. Conversely, CBCT has become the preferred imaging modality for implant planning, sinus lift procedures, orthodontic assessment, and evaluation of cystic or neoplastic lesions involving the posterior maxilla [3,11,20,28-30]. Therefore, the present study aimed to compare the diagnostic performance of panoramic radiography (OPG) and cone beam computed tomography (CBCT) in detecting maxillary sinus pathologies and to assess the reliability of OPG in identifying sinus abnormalities using CBCT as the reference standard.

Methods

Study Design and Ethical Considerations

A retrospective cross-sectional study was conducted using panoramic radiographs (OPG) and cone beam computed tomography (CBCT) scans collected from public dental clinics in Misurata, Libya. The study included panoramic radiographs obtained from male and female patients with radiographic findings suggestive of maxillary sinus pathology, without gender-based stratification. Ethical approval was obtained from the Research and Consultation Office, Faculty of Dentistry, Misurata University, Misurata, Libya, and all patient data were anonymized prior to analysis.

Study Sample

A total of 437 panoramic radiographs were evaluated for radiographic evidence of maxillary sinus pathology. Among these, 316 patients additionally underwent CBCT imaging on the same day, allowing direct comparison between both imaging modalities under identical anatomical and pathological conditions. Included cases demonstrated radiographic evidence of maxillary sinus pathology, including mucosal thickening, odontogenic and non-odontogenic sinusitis, mucous retention cysts, polyps, fluid accumulation, foreign bodies, oroantral fistulas, and mucoceles. Cases with severe imaging artifacts or incomplete radiographic data were excluded to ensure diagnostic reliability and consistency.

Image Acquisition and Interpretation

All radiographic examinations were acquired using the Carestream 3D Imaging System (Carestream Dental LLC, Atlanta, GA, USA) following the manufacturer's recommended imaging protocols. Panoramic radiography was used as the initial imaging modality, whereas CBCT served as the reference standard because of its superior spatial resolution and three-dimensional visualization of maxillary sinus anatomy and pathology. [32–34] Panoramic radiographs were independently interpreted by two experienced oral pathologists. CBCT images were evaluated by a single experienced oral pathologist and served as the reference standard for lesion confirmation and assessment of anatomical extent and tooth–sinus relationships.

Diagnostic Criteria

Diagnostic criteria described by Maillet *et al*.[21] were adopted to classify maxillary sinus lesions. Odontogenic sinusitis was diagnosed when sinus mucosal thickening or opacification was associated with adjacent dental pathology, whereas non-odontogenic sinusitis was diagnosed in the absence of dental disease. Mucosal thickening was defined as Schneiderian membrane thickness exceeding 1 mm, while localized thickening greater than 5 mm was classified as a mucous retention cyst or polyp. Fluid accumulation was identified by the presence of an air–fluid level within the sinus cavity. Mucoceles were diagnosed based on complete sinus opacification associated with sinus expansion and thinning of the surrounding cortical walls. Oroantral fistulas were identified as osseous discontinuities communicating with the oral cavity. Malignant lesions were assessed based on radiographic evidence of bone destruction and invasive characteristics; however, no tumors were identified.

Observer Reliability

To assess intra-observer reliability, randomly selected CBCT examinations were re-evaluated by the principal observer after a four-week interval. In addition, representative OPG-only cases with characteristic radiographic findings of maxillary sinus pathology were included to illustrate the diagnostic capability of panoramic radiography for detecting obvious lesions.

Statistical Analysis

Descriptive statistics were expressed as frequencies and percentages. Statistical analyses were performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). The association between pathology type and OPG detection was evaluated using the Chi-square (χ^2) test, whereas McNemar's test was used to compare paired OPG and CBCT findings. Statistical significance was set at $P < 0.05$.

Results

A total of 437 panoramic radiographs (OPG) were evaluated for maxillary sinus pathology. Among these, 316 patients additionally underwent cone beam computed tomography (CBCT) on the same day, allowing direct comparison between

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the two imaging modalities under identical anatomical conditions. Representative normal and pathological cases are presented to illustrate the radiographic characteristics of maxillary sinus findings on both OPG and CBCT. Normal maxillary sinuses demonstrated clear aeration without evidence of mucosal thickening, cystic lesions, fluid accumulation, or odontogenic pathology (Figure 1 and 2).

Representative pathological cases demonstrated that the diagnostic performance of panoramic radiography varied according to lesion type and extent. CBCT consistently provided superior visualization of sinus anatomy, lesion morphology, lesion extent, and tooth–sinus relationships, whereas the diagnostic value of OPG depended largely on lesion size, location, and radiographic conspicuity. Subtle pathological findings, particularly mild mucosal thickening and early inflammatory changes, were frequently underestimated or poorly visualized on panoramic radiographs (Figure 3). In several cases, OPG demonstrated only nonspecific reduction in sinus radiolucency without permitting a definitive diagnosis. In contrast, CBCT clearly identified mucosal thickening, accurately assessed lesion extent, and differentiated inflammatory mucosal alterations from cystic lesions (Figure 4).

Conversely, larger and well-demarcated lesions such as mucous retention cysts and mucosal polyps were more readily identifiable on panoramic radiography. Dome-shaped radiopacities arising from the sinus floor were frequently visible on OPG, particularly when lesions were large and located inferiorly within the sinus cavity (Figure 5). CBCT remained superior for confirming lesion diagnosis, characterizing lesion morphology, assessing disease extent, and excluding associated osseous destruction or odontogenic involvement. (Figure 6) Cases of odontogenic sinusitis further highlighted the diagnostic value of CBCT in establishing the relationship between infected posterior maxillary teeth and sinus pathology. CBCT clearly demonstrated continuity between periapical lesions and sinus mucosal inflammation, thereby confirming the odontogenic origin (Figure 7). Although panoramic radiographs frequently suggested sinus involvement through increased radiopacity adjacent to diseased teeth (Figure 8), precise characterization and confirmation of odontogenic extension were possible only with CBCT imaging. Despite the absence of CBCT confirmation (Figure 9-12), these panoramic radiographs revealed clear and easily recognizable signs of maxillary sinus pathology, such as mucosal thickening, retention cysts, or sinusitis-related fluid accumulation. The radiopacities were well-defined, often dome-shaped, and located near the sinus floor, making them readily recognizable on panoramic imaging.

Even in a two-dimensional format. CBCT also demonstrated superior diagnostic performance in identifying multiple simultaneous lesions, differentiating diffuse mucosal thickening from localized polyps, and evaluating anatomical variations such as root protrusion into the maxillary sinus. Panoramic radiography was limited by anatomical superimposition, reduced contrast resolution, and its inability to assess buccolingual relationships. Despite these limitations, selected OPG-only cases demonstrated that panoramic radiography may still provide clinically valuable information when lesions are large, well-defined, and radiographically conspicuous. These findings support the role of OPG as a practical first-line screening modality, particularly in routine dental practice or when CBCT is unavailable. Overall, the findings demonstrated that CBCT exhibited superior diagnostic accuracy in detecting and characterizing maxillary sinus pathology, particularly in subtle, complex, and odontogenic lesions. Nevertheless, panoramic radiography remained useful for the initial identification of obvious sinus abnormalities and may assist in determining the need for advanced imaging. The distribution of maxillary sinus pathologies is summarized in Figures 13 and 14, and the comparative diagnostic performance of OPG and CBCT is presented in (Table 1). Statistical analysis demonstrated that the diagnostic performance of panoramic radiography varied significantly according to lesion type ($\chi^2 = 71.38$, $P < 0.001$). Furthermore, McNemar's test confirmed that CBCT detected significantly more maxillary sinus pathologies than panoramic radiography ($\chi^2 = 114.9$, $P < 0.001$), confirming the superior diagnostic performance of CBCT, particularly for subtle inflammatory lesions., particularly for subtle inflammatory lesions.

Table 1. Comparison of OPG and CBCT Findings in Maxillary Sinus Pathology

Finding	CBCT diagnosis (n)	Detected on OPG	Missed on OPG	Total
Mucosal thickening	86	35	51	86
Non-odontogenic sinusitis	51	16	35	51
Odontogenic sinusitis	24	18	6	24
Polyp	23	20	3	23
Mucous retention cyst	31	24	7	31
Foreign body	7	6	1	7
Normal sinus	94	80	14	94
Total paired cases	**316**	**199**	**117**	**316**

Table -1 Comparison of panoramic radiography (OPG) and cone beam computed tomography (CBCT) findings in the paired study population (n = 316). CBCT served as the reference standard. OPG-positive indicates lesions correctly identified on panoramic radiography, whereas OPG-negative represents lesions detected on CBCT but not identified on panoramic radiography.

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Figure 1- Normal panoramic radiograph showing clear, aerated maxillary sinuses with intact borders and no pathology.

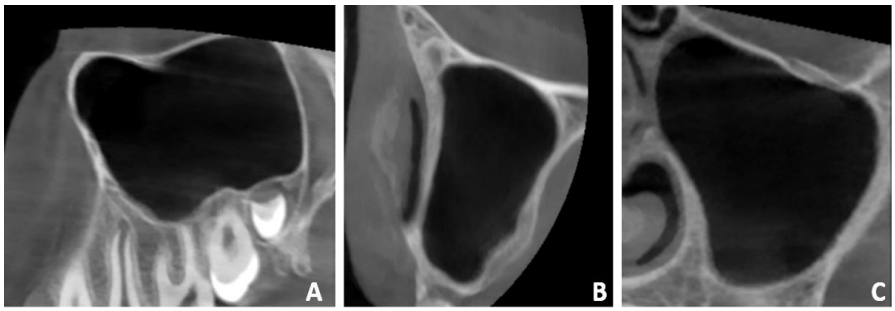

Figure 2- CBCT images in multiple planes showing fully aerated maxillary sinuses with intact bony walls and no evidence of mucosal thickening, fluid accumulation, or other pathology.

Figure 3-Panoramic image shows no definitive sign of mucosal change. The sinus appears slightly opaque on the right side, but diagnostic confirmation is not possible on OPG alone.

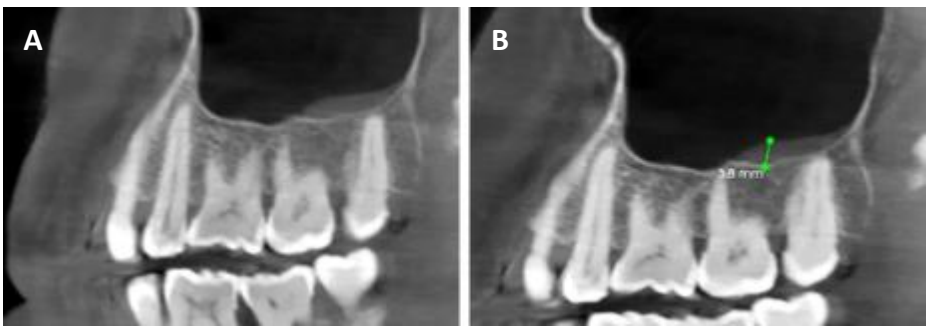

Figure 4- A. Coronal section CBCT- radiographic views of a patient with mucosal thickening in the right maxillary sinus. B. Soft tissue lining the sinus floormeasures 3.8 mm, indicating chronic mucosal thickining

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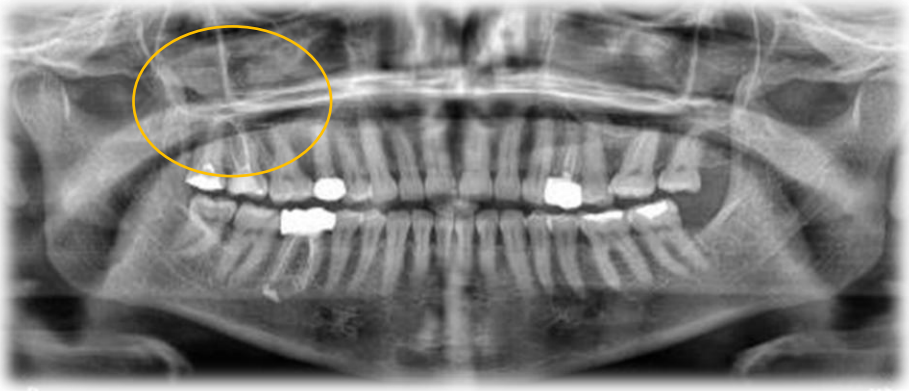

Figure5- Panoramic radiograph (OPG) clearly depicts a dome-shaped radiopacity in the right sinus, consistent in location and morphology with the CBCT finding.

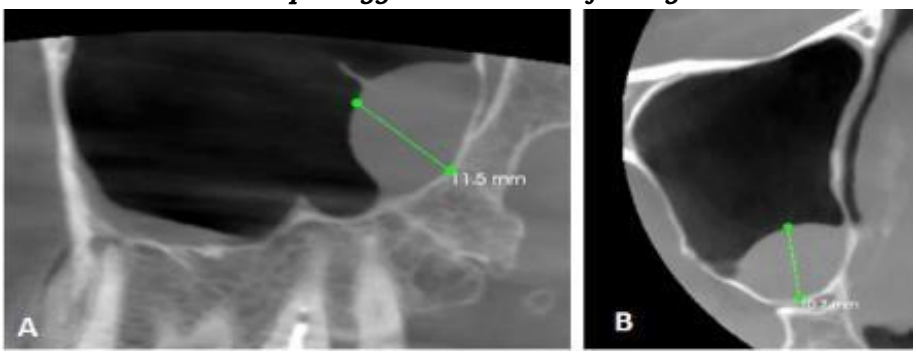

Figure 6- Comparative imaging of a mucous retention cyst in the right maxillary sinus. A. Coronal CBCT slice showing a dome-shaped soft tissue mass arising from the sinus floor, measuring 11.5mm. B. Sagittal CBCT image with vertical measurement of 10.7 mm, confirming its extension and rounded contour.

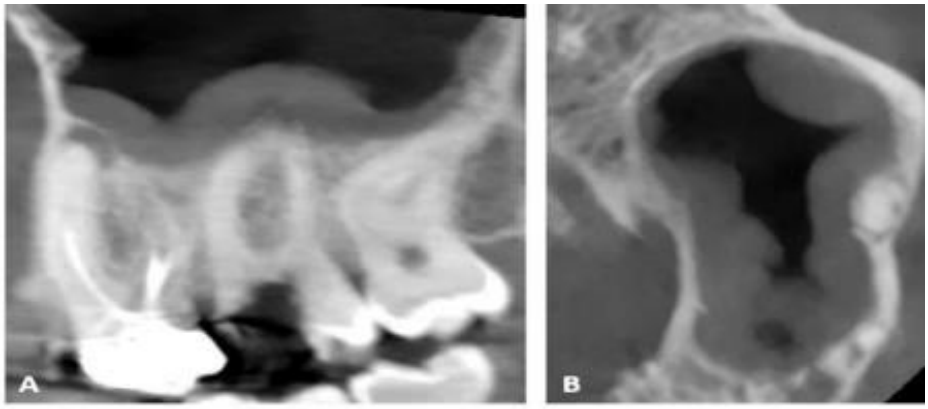

Figure 7- Radiographic evaluation of chronic odontogenic maxillary sinusitis associated with a grossly decayed left maxillary second molar. A – Coronal CBCT view shows extensive mucosal thickening and partial opacification of the left maxillary sinus, in continuity with the apex of a decayed molar. B – Sagittal CBCT view confirms chronic sinus lining thickening with irregular contours and no fluid level, consistent with long-standing inflammation.

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Figure 8- Panoramic radiograph (OPG) reveals a severely decayed left maxillary second molar and increased radiodensity in the adjacent sinus region, suggestive of sinusitis.

Figure 9- Panoramic radiograph showing partial opacification of the left maxillary sinus, evident as a dome-shaped radiopaque area suggestive of a mucosal thickening. The right maxillary sinus appears normally aerated.

Figure 10- OPG showing well defined dome-shaped radiopacity in the right maxillary sinus, suggestive of a mucosal retention cyst.

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Figure- 11 Panoramic radiograph demonstrating bilateral maxillary sinus opacities. Both sinuses exhibit rounded radiopaque lesions originating from the sinus floor, highly suggestive of mucosal retention cysts or localized mucosal thickening. The symmetrical appearance and well-defined borders support a benign, non-aggressive process

Figure 12 -Panoramic radiograph showing a well-defined radiopaque mass within the left maxillary sinus (arrow), likely representing a benign bony entity such as an osteoma or an antral exostosis. The lesion is homogeneous in density and distinct from surrounding soft tissue, suggesting a bony origin rather than a soft tissue lesion like a mucosal cyst.

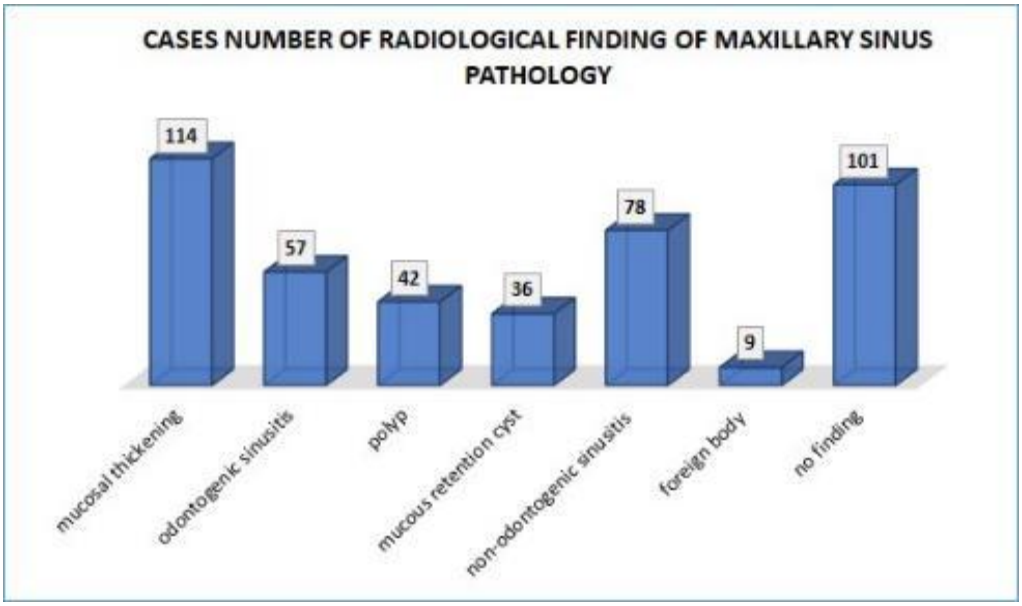

Figure -13 Cases number of radiological finding of maxillary sinus pathology

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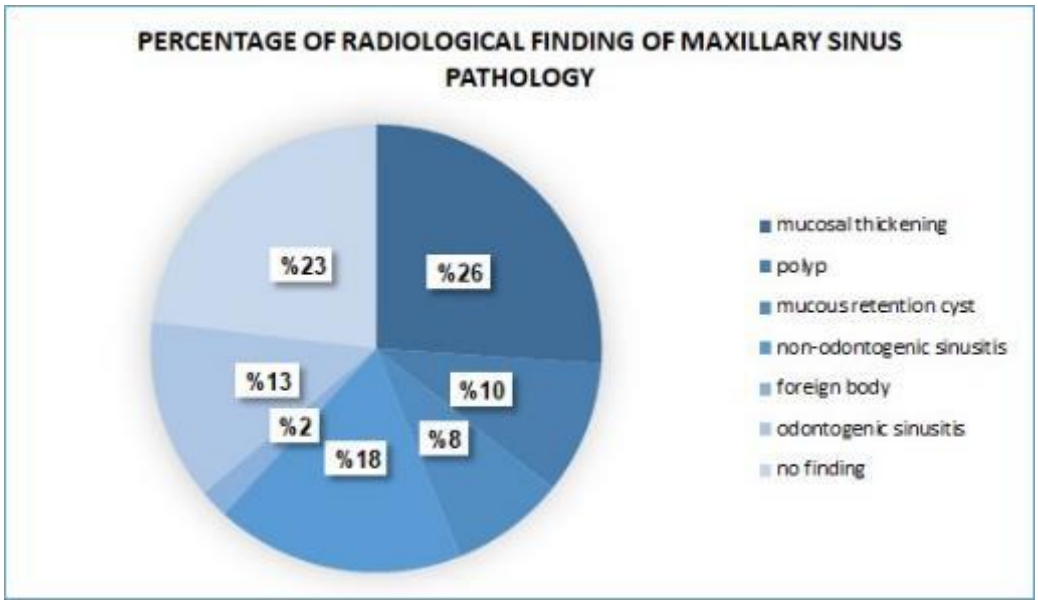

Figure -14_Percentage of radiological finding of maxillary sinus pathology

Discussion

The present study evaluated the diagnostic performance of panoramic radiography (OPG) in detecting maxillary sinus pathology compared with cone beam computed tomography (CBCT), while also assessing circumstances in which OPG alone may provide clinically sufficient diagnostic information. Among the 437 evaluated cases, mucosal thickening represented the most common radiographic finding (26%), followed by non-odontogenic sinusitis (18%), odontogenic sinusitis (13%), mucosal polyps (10%), and mucous retention cysts (8%). These findings are consistent with previous CBCT-based studies reporting mucosal thickening as the most prevalent incidental maxillary sinus abnormality [20,22,23]. The results demonstrated that CBCT provides superior diagnostic accuracy for maxillary sinus evaluation because of its high spatial resolution and three-dimensional imaging capability. Subtle inflammatory changes, mild mucosal thickening, early sinus disease, and complex anatomical relationships were consistently better visualized on CBCT than on panoramic radiography. These findings are consistent with previous studies reporting the limited sensitivity of panoramic radiography in detecting early or subtle maxillary sinus pathology [11,16-18,25,26,31].

Statistical analysis demonstrated a highly significant association between pathology type and OPG detection capability (χ^2 = 71.38, $p < 0.001$), indicating that the diagnostic performance of panoramic radiography depends largely on lesion morphology and radiographic conspicuity. Panoramic radiography demonstrated greater diagnostic reliability for large, well-defined lesions such as mucous retention cysts, polyps, and foreign bodies, whereas diffuse inflammatory lesions, particularly mucosal thickening and non-odontogenic sinusitis, were frequently underestimated or missed. Furthermore, McNemar's test demonstrated a statistically significant difference between OPG and CBCT in detecting maxillary sinus pathology (χ^2 = 114.9, $p< 0.001$), confirming that CBCT identified substantially more pathological findings than panoramic radiography. These findings are consistent with those reported by Rege et al. [35], who concluded that panoramic radiography has limited diagnostic value in evaluating maxillary sinus disease, particularly in asymptomatic patients and subtle inflammatory conditions.

Despite these limitations, the present study demonstrated that panoramic radiography may still provide clinically useful information when lesions are large, well-circumscribed, and located near the sinus floor. Several OPG-only cases demonstrated characteristic radiographic appearances, including dome-shaped radiopacities associated with mucous retention cysts and extensive sinus opacification suggestive of chronic sinusitis. These findings support the continued role of panoramic radiography as an accessible and cost-effective first-line imaging modality in routine dental practice. An additional observation was the significant influence of image quality on OPG diagnostic performance. Variations in patient positioning, exposure settings, and image sharpness affected lesion detectability.

Optimized panoramic imaging parameters improved visualization of sinus abnormalities, suggesting that standardization and quality assurance protocols may enhance the diagnostic utility of panoramic radiography for obvious or advanced lesions. CBCT also demonstrated substantial value in evaluating the anatomical relationship between the posterior maxillary tooth roots and the maxillary sinus floor. Its three-dimensional imaging capability enables accurate assessment of root protrusion, sinus floor integrity, and odontogenic extension, thereby improving the evaluation of maxillary sinus pathology. These findings are consistent with previous studies highlighting the diagnostic advantages of CBCT in assessing tooth–sinus relationships and maxillary sinus anatomy [16,17,21]. Nevertheless, panoramic radiography remains limited by its two-dimensional nature, anatomical superimposition, distortion, and inability to accurately evaluate buccolingual relationships. Consequently, reliance on panoramic radiography alone may lead to underdiagnosis of early or subtle sinus disease. The present study has several limitations. First, its retrospective design may introduce selection bias. Second,

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histopathological confirmation was not available for all lesions, and diagnosis relied primarily on radiographic interpretation. In addition, CBCT examinations were available only for a subset of patients, which may influence direct modality comparison. Nevertheless, the relatively large sample size and inclusion of paired OPG–CBCT cases strengthen the clinical relevance of the findings. Overall, the present findings support a stepwise imaging approach in which panoramic radiography is used for initial screening, followed by CBCT in cases requiring detailed anatomical evaluation, surgical planning, or clarification of equivocal findings. Such an evidence-based approach may optimize diagnostic accuracy while minimizing unnecessary radiation exposure and healthcare costs.

Conclusion

The present study demonstrated that cone beam computed tomography (CBCT) provides superior diagnostic performance compared with panoramic radiography (OPG) in the evaluation of maxillary sinus pathology, particularly for subtle inflammatory lesions, odontogenic extension, and complex anatomical conditions. CBCT enables more accurate assessment of lesion morphology, disease extent, and tooth–sinus anatomical relationships because of its three-dimensional imaging capability. Although panoramic radiography showed lower sensitivity for early or diffuse sinus disease, it remained effective in detecting obvious and well-defined lesions, including mucous retention cysts, mucosal polyps, and advanced sinus opacification. Therefore, panoramic radiography remains a valuable, accessible, and cost-effective first-line imaging modality for the initial evaluation of maxillary sinus pathology. However, CBCT should be considered when subtle inflammatory disease, suspected odontogenic extension, or detailed anatomical assessment is required. A stepwise imaging approach integrating both modalities may improve diagnostic accuracy, support appropriate clinical decision-making, and optimize patient management.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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