REVIEW ARTICLE

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Cone-Beam CT, CT and MRI for odontogenic tumors: a narrative review of imaging characteristics

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ABSTRACT

Objectives: This review article aims to examine the role of cone-beam computed tomography (CBCT) in the diagnosis and management of odontogenic tumors. Additionally, it evaluates CBCT's efficacy in the assessment of both benign and malignant odontogenic tumors, including ameloblastoma, odontoma, and odontogenic myxoma.

Review: This narrative review provides an in-depth analysis of CBCT imaging characteristics in the most common odontogenic tumors. The review highlights key CBCT features such as localization, peripheral structure, and internal architecture, emphasizing their impact on surrounding tissues. It compares the utility of CBCT with that of CT and MRI for the diagnosis of common odontogenic tumors, focusing on the strengths and weaknesses of each modality. The research questions addressed in this review include how CBCT can enhance diagnostic accuracy, what imaging characteristics are critical for differentiation between benign and malignant tumors, and how CBCT compares with traditional imaging methods in the context of maxillofacial tumor diagnostics.

Conclusion: CBCT's three-dimensional imaging capabilities provide clinicians with enhanced visualization of odontogenic tumor characteristics, aiding in accurate lesion localization, differentiation of tumor types, and treatment planning. CBCT is particularly useful for assessing the internal structure and peripheral boundaries of odontogenic tumors, improving the ability to distinguish between benign and malignant lesions. However, its limitations in soft tissue resolution underscore the continued importance of CT and MRI in comprehensive maxillofacial imaging.

Keywords: *Ameloblastoma, odontogenic tumors, benign lesions, CBCT 3D, maxillofacial imaging*
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INTRODUCTION

Maxillofacial imaging has seen significant advancements over the past decades, with cone-beam computed tomography (CBCT) emerging as a pivotal diagnostic tool following the widespread use of panoramic radiography. Initially developed in the early 1980s for angiography, CBCT found its way into dentistry by the early 1990s and has since become indispensable in evaluating dentoalveolar structures.[1,2] By utilizing a cone- or pyramid-shaped ionizing radiation source and a rotating gantry attached to a two-dimensional detector, CBCT produces volumetric images with high resolution and isotropic voxel size.[3]

This review aims to explore the role of CBCT in diagnosing odontogenic tumors, its strengths and limitations, and its comparison with medical CT and magnetic resonance imaging (MRI). Additionally, the most common odontogenic tumors and their specific imaging characteristics are discussed to enhance the understanding and diagnostic accuracy of clinicians.

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REVIEW

This review was conducted by analyzing literature related to CBCT findings in odontogenic tumors. Articles published between 1990 and 2023 were reviewed from databases such as PubMed, Scopus, and Web of Science. The search terms used included *"cone-beam computed tomography"*, *"odontogenic tumors"*, *"ameloblastoma"*, *"odontoma"*, *"odontogenic myxoma"*, and *"malignant odontogenic tumors"* to include the most common odontogenic tumors' imaging characteristics in this study. Inclusion criteria were English-language studies that discussed the imaging features of odontogenic tumors with a specific focus on CBCT findings. Exclusion criteria included studies focused solely on non-odontogenic lesions and those without CBCT imaging results.

ODONTOGENIC TUMORS

Odontogenic tumors are a diverse group of neoplasms that originate from the tissues involved in tooth development, including the enamel, dentin, cementum, and their associated structures.[4] These tumors vary widely in their biological behavior, ranging from benign, slow-growing lesions to aggressive, malignant tumors capable of local invasion and distant metastasis.[5,6] Although they are relatively rare, odontogenic tumors are of significant clinical importance due to their potential impact on the jaws and surrounding tissues.[6] Accurate diagnosis and proper management are crucial, as some odontogenic tumors may mimic other maxillofacial pathologies. Imaging modalities, particularly CBCT, play a vital role in identifying and characterizing odontogenic tumors, offering detailed insights into their localization, internal architecture, and effects on adjacent structures.[7, 8] Understanding the imaging features of odontogenic tumors is essential for clinicians to differentiate between benign and malignant forms, ensure appropriate treatment planning, and prevent unnecessary interventions.

AMELOBLASTOMA

Ameloblastomas are the most common odontogenic tumors, accounting for approximately 80% of cases in the posterior mandible.[9-10] CBCT plays a crucial role in their evaluation, as it offers superior spatial resolution and detailed imaging of both the tumor and surrounding structures. Ameloblastomas are most commonly found in the posterior mandible and typically present with well-defined, corticated borders.[11] CBCT imaging reveals that ameloblastomas may appear as either multilocular, exhibiting a honeycomb or soap bubble appearance, or as unilocular radiolucent lesions (Figure 1). The septa within the tumor are often thick and curved, representing residual bone without reactive bone formation (Figure 2). Ameloblastomas exert significant pressure on surrounding structures, leading to cortical bone expansion, destruction, and even perforation. Additionally, root resorption and tooth displacement are frequently observed.[11-13]

On CT, ameloblastomas typically present with well-defined borders and low internal attenuation. The locularity of these tumors varies, with some showing a honeycomb-like appearance and others appearing unilocular.[14] All cases exhibit bone expansion, primarily on the labial side. MRI findings demonstrate well-defined borders with solid, moderately low signal intensities and small cystic high-signal intensities on T2-weighted images, while intermediate signal intensities are noted on T1-weighted images. Linear low signal intensity on both T1- and T2-weighted images was observed in several cases. Gadolinium-enhanced MRI revealed moderate enhancement in all cases, with dynamic-enhanced MRI showing persistent enhancement, suggesting solid components within the lesion.[15,16] These findings help differentiate ameloblastomas from other cystic lesions in the maxillomandibular region, such as odontogenic keratocysts, especially due to the high recurrence rates of both. MRI is particularly valuable for detecting the mixed solid and cystic patterns, thickened walls, and strong

Figure 1. (A) Sagittal CBCT section illustrating the characteristic "soap bubble" appearance. (B) Sagittal and (C) axial sections of the same ameloblastoma demonstrating the multilocular structure. Arrows highlight the multilocular features.

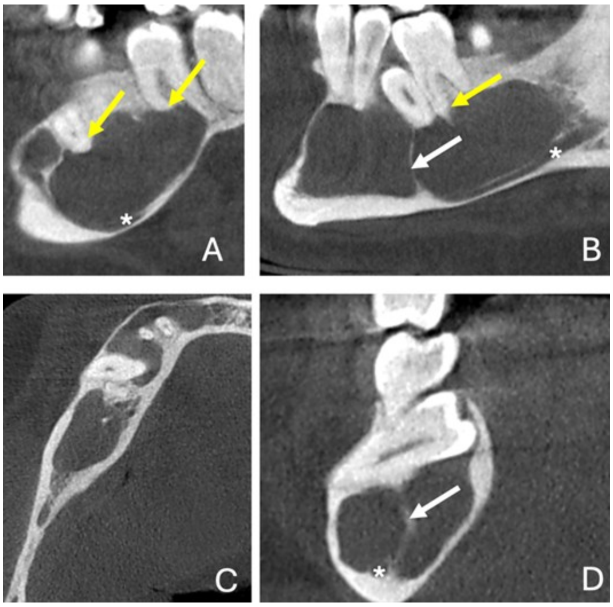

Figure 2. (A, B) Sagittal CBCT images and (C, D) axial CBCT images depicting the septa formation characteristic of ameloblastoma. Yellow arrows indicate root resorption, while white arrows point to the septa formation. The asterisk marks the inferior displacement of the mandibular canal

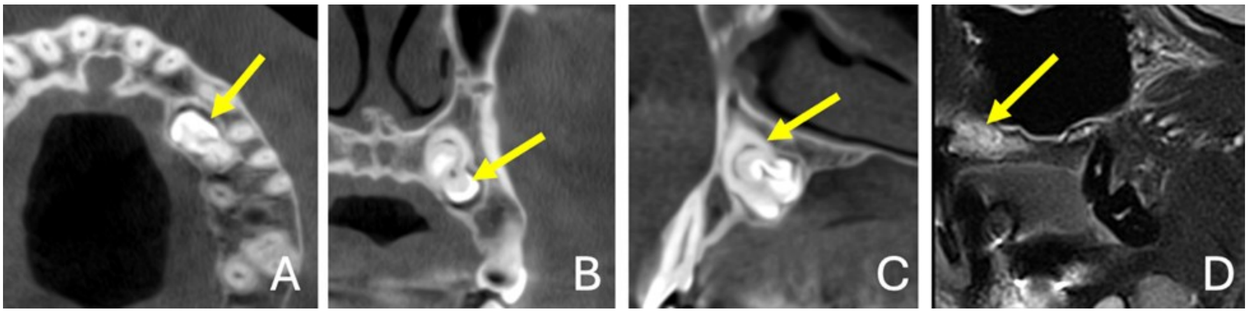

Figure 3. (A, B, C) Axial, coronal, and sagittal CBCT sections of an odontoma, highlighting its mixed radiographic appearance and well-defined peripheral borders. (D) Sagittal section of a Spin Echo Magnetic Resonance Image of the odontoma, displaying both hyperintense and hypointense structures. Arrows denote the complex odontoma

enhancement of solid components, which are characteristic of ameloblastomas.[15]

ODONTOMA

Odontomas are benign odontogenic tumors composed of fully differentiated dental tissues such as enamel, dentin, cementum, and pulp.[17] They are often considered hamartomas rather than true neoplasms due to their limited growth potential. Odontomas are most frequently found in the maxilla.[18] On CBCT, they appear as well-defined, hyperdense lesions with a density similar to dental tissues. These tumors are often associated with unerupted teeth, and CBCT imaging is particularly useful in determining the extent of tooth impaction and buccolingual inclination.[19] There are two types of odontomas: Complex odontomas, which present as amorphous masses with varying densities and are typically surrounded by a hypodense border, and compound odontomas, which consist of multiple tooth-like structures of varying density and are characterized by a hypodense margin (Figure 3).[20-22]

ODONTOGENIC MYXOMA

Odontogenic myxomas are benign tumors that arise exclusively from the facial skeleton, particularly the posterior mandible.[23,24] CBCT is valuable in identifying these lesions due to their subtle radiographic presentation and varied internal structure.[25-27] The peripheral boundaries of these tumors may present as either corticated or diffuse, with scalloping observed in some cases. Internally, odontogenic myxomas are typically multilocular, often displaying a honeycomb or soap bubble appearance.[24-26] The septa within the tumor are usually straight and thin, which helps differentiate them from ameloblastomas, where the septa tend to be more curved. Tooth displacement is a common effect on surrounding structures, although root resorption is rare. In some instances, cortical expansion may occur, though it is generally less pronounced than in ameloblastomas.[25-27]

Radiological findings, such as the presence of tooth resorption, septa formation, and perforation, were not found to be associated with recurrence.[24] In multilocular lesions, the frequency of expansion and perforation was higher compared to unilocular lesions. The recurrence rate may vary depending on the treatment methods used. Tooth mobility is rarely observed, and paresthesia may occur in some cases.[29]

MRI findings of odontogenic myxoma often help distinguish it from ameloblastomas, although the two can appear similar on conventional radiographs. On MRI, odontogenic myxomas commonly show intermediate signal intensity on T1 -weighted images (T1WI) and homogeneous high signal intensity on T2-weighted images (T2WI).[30] Dynamic MRI has been shown to differentiate these lesions effectively. In ameloblastomas, the solid areas typically exhibit rapid enhancement, reaching peak contrast between 45-60 seconds, followed by either sustained enhancement or gradual wash-out over the next 600 seconds. In contrast, the cystic areas of ameloblastomas show no enhancement. Odontogenic myxomas, on the other hand, show a gradual increase in enhancement across the whole tumor area, including the central portions, with a peak at 500-600 seconds. This gradual enhancement pattern seen in myxomas, even in areas not initially enhanced on Gd-T1 weighted images, is minimal but distinctive. Post-contrast MRI (Gd-T1WI) reveals peripheral rim enhancement, corresponding to the fibrous capsule seen histopathologically. The central portion of the myxoma, which shows no enhancement on Gd-T1WI, consists of poorly differentiated cellular mucoid matrix. Therefore, dynamic MRI, with its ability to capture these differences in enhancement patterns, is a useful diagnostic tool for differentiating odontogenic myxomas from ameloblastomas.[31,32]

MALIGNANT AMELOBLASTOMA

Malignant ameloblastoma is known for its potential to recur even after many years, often complicating long-term management.[33-35] Despite being histologically benign, its biological behavior includes aggressive local invasion and a high recurrence rate, especially in cases where the tumor is not entirely excised.[34,35] Malignant ameloblastomas can metastasize to distant sites, with the lungs being the most frequent target, as observed in several reported cases.[33-41] For example, a case report highlighted a patient developing pulmonary metastases 45 years after the initial diagnosis, emphasizing the indolent yet persistent nature of this tumor.[38]

Given the potential for late recurrence and metastasis, imaging plays a crucial role in both the initial diagnosis and follow-up of malignant ameloblastomas. CBCT plays a key role in detecting metastasis and local recurrence. Malignant ameloblastomas primarily affect the mandible, particularly in the premolar and molar regions. On CBCT, these tumors exhibit variable imaging patterns, ranging from well-corticated borders to ill-defined margins with evidence of soft tissue invasion. Internally, malignant ameloblastomas can present as unilocular or multilocular lesions, often displaying a honeycomb or soap bubble appearance. Additionally, CBCT frequently reveals cortical bone destruction and invasion into adjacent tissues, underscoring the aggressive nature of these tumors.[34-38] PET-CT, in particular, has proven to be a valuable tool in detecting recurrent or metastatic disease.[34] PET-CT combines metabolic imaging with anatomical detail, enabling clinicians to assess both the primary tumor and distant metastases. FDG-PET imaging has shown promise in detecting metabolically active regions of ameloblastomas, particularly in distinguishing malignant transformations from benign recurrences.[34]

DISCUSSION

Odontogenic tumors, particularly ameloblastomas and odontogenic myxomas, present significant diagnostic challenges due to their diverse presentations, growth patterns, and potential for recurrence.[4,7-9] The utility of CBCT and other imaging modalities such as CT and MRI in the evaluation of these tumors cannot be overstated. These imaging technologies are critical for assessing tumor characteristics, guiding treatment decisions, and predicting potential outcomes, including recurrence and metastasis.[11,14,34,35] CBCT's ability to provide three-dimensional, high-resolution images of bone structures makes it indispensable for assessing odontogenic tumors.[6] CBCT excels in visualizing bony details, making it especially useful in cases where tumors infiltrate the mandible or maxilla.[7,8] Ameloblastomas, which most commonly affect the posterior mandible, are often multilocular, displaying a honeycomb or soap bubble appearance on CBCT scans . This imaging modality offers excellent spatial resolution, allowing clinicians to assess not only the tumor's internal structure but also its impact on surrounding bone, such as cortical expansion or destruction. Similarly, odontogenic myxomas exhibit multilocular radiolucencies on CBCT, often with thin septa.[12-14]

CBCT's relatively low radiation dose compared to medical CT and its capacity to provide isotropic voxel data have contributed to its widespread use in dental and maxillofacial radiology.[2,3] However, CBCT's primary limitation lies in its inability to provide detailed soft tissue contrast.[3] This makes it less effective for evaluating soft tissue involvement or detecting malignant transformation, necessitating the use of complementary imaging modalities such as MRI and FDG-PET.[16,34,35] CT scans are particularly useful for detecting cortical bone destruction and soft tissue invasion, especially in cases of malignant ameloblastomas. Malignant ameloblastomas often present with ill-defined margins on CT, indicating aggressive infiltration of surrounding tissues. This capability is critical in treatment planning, particularly for surgical excision. Additionally, contrast-enhanced CT can help to differentiate cystic from solid components within the tumor, which is important for accurate diagnosis.[42,43] The use of contrast helps to distinguish cystic lesions from solid or vascular structures, as the cystic areas typically appear as non-enhancing or minimally enhancing compared to solid tissue, which absorbs the contrast medium.[42,43]

MRI plays a complementary role by providing superior soft tissue contrast, making it indispensable for evaluating tumors with complex internal structures or those that invade soft tissues. Dynamic MRI has been shown to effectively differentiate between ameloblastomas and odontogenic myxomas based on their enhancement patterns. In ameloblastomas, the solid areas typically demonstrate rapid enhancement with contrast, followed by a gradual washout, whereas cystic areas show no enhancement. In contrast, odontogenic myxomas exhibit gradual enhancement across the entire lesion, including regions that may appear unenhanced on initial scans. This difference in enhancement patterns is crucial for distinguishing these two entities, which can appear radiographically similar on conventional imaging.[30-32]

One of the most concerning aspects of treating odontogenic tumors, particularly ameloblastomas, is their high recurrence rate.[34-41] Even after seemingly successful resection, ameloblastomas can recur many years later, as demonstrated by case reports describing recurrences up to 45 years after initial treatment.[38] This prolonged risk of recurrence underscores the need for long-term imaging surveillance, which should include regular CBCT scans to assess for bony changes and FDG-PET/CT or MRI for detecting soft tissue or metastatic involvement.

The comparative utility of CBCT, CT, MRI, and PET/CT in diagnosing and monitoring odontogenic tumors depends on the specific clinical scenario. CBCT is ideal for initial assessments of bony involvement and for monitoring post-surgical bony healing. However, when soft tissue involvement or malignant transformation is suspected, MRI and FDG-PET/CT provide the necessary additional information. CT remains a valuable tool for assessing cortical bone integrity and detecting subtle changes that may indicate aggressive tumor behavior.

CONCLUSION

This review has highlighted the strengths and limitations of CBCT, medical CT and MRI, for assessing common benign and malignant odontogenic tumors such as ameloblastomas, odontomas, and odontogenic myxomas. CBCT's ability to provide visualization of tumor localization, peripheral boundaries, internal structures, and effects on surrounding tissues makes it a valuable asset.

While CBCT excels in hard tissue assessment, complementary imaging modalities like MRI and PET-CT are crucial for evaluating soft tissue involvement and detecting tumor recurrence or metastasis. In particular, PET-CT has proven to be highly effective in identifying recurrent or metastatic malignant ameloblastomas, which have the potential to recur even decades after initial treatment. Dynamic MRI also aids in distinguishing between odontogenic tumors, particularly in differentiating odontogenic myxomas from ameloblastomas based on enhancement patterns.

Utilizing CBCT, MRI, and PET-CT is essential for comprehensive evaluation. CBCT remains a cornerstone in oral and maxillofacial diagnostics, while advanced imaging modalities contribute to broader evaluation of the odontogenic tumors.

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FOOTNOTES

All authors have no potential conflict of interest to declare for this article.

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