The European Research Journal 2025;11(1):105-112 Original Article

DOI: https://doi.org/10.18621/eurj.1587815 *Medical Pathology*

Correlation of radiological and histopathological findings in the diagnosis of benign bone tumors

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ABSTRACT

Objectives: Diagnosis of benign bone tumors is one of the diagnostic questions in the clinical practice which has an impact on the patient's quality of life. The work aimed to define the radiographic and histologic complementary diagnosis for benign bone tumors.

Methods: The present cross-sectional study included one hundred and forty-two patients with benign bone and soft tissue tumors referred to and followed up in the Adana Seyhan Hospital over a study period of 2010 to 2023. Patients were categorized based on the tumor type and radiological imaging was done through X-ray, Computed Tomography (CT), and Magnetic Resonance Imaging (MRI) scans. These results were then compared to histopathologic outcomes. Diagnostic indices such as the percentage accuracy, sensitivity, specificity, and positive and negative predictive values were estimated.

Results: In the study, 43.7% of the tumors were cartilaginous. MRI had the highest diagnostic accuracy (sensitivity of 96.9%, specificity of 83.3%, $P<0.05$). X-ray showed sensitivity of 90.8% and specificity of 66.7%, while CT showed sensitivity of 92.3% and specificity of 58.3%. A strong correlation was observed between radiologic and histopathologic findings ($r=0.87$, $P<0.001$).

Conclusions: Out of the histopathological features, there is a closely related association between the radiological and histopathological appearances in the diagnosis of benign bone tumors. Magnetic Resonance Imaging appears to be the only imaging modality with high accuracy of diagnosis. The concomitant interpretation of radiologic and histopathologic features allows for a considerable enhancement in diagnostic specificity.

Keywords: Benign bone tumors, radiological diagnosis, histopathological correlation

Benign bone tumors are those tumors that develop in the bones and do not display any malignant characteristics. Generally, these tumors are benign and slow-growing, with a lack of invasive behavior [1]. However, they can precipitate clinically relevant issues, for example, pain, edema, and pathologic fracture based on the area of involvement [2]. Therefore, it is essential to address the various challenges associated with diagnosing and treating benign bone tumors, as this impacts the overall well-being of affected patients and may subject them to unnecessary aggressive therapies [3]. Hence, early and correct identification of benign bone tumors is significant [4].

Radiography, Computed Tomography (CT) scans, and Magnetic Resonance Imaging (MRI) serve as important imaging techniques for the diagnosis of benign

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How to cite this article: Eriten B, Menekşe S. Correlation of radiological and histopathological findings in the diagnosis of benign bone tumors. Eur Res J. 2025;11(1):105-112. doi: 10.18621/eurj.1587815

Received: November 19, 2024
Accepted: December 26, 2024
Published Online: .December 31, 2024

bone tumors. However, some benign lesions may present with radiological features that may mimic those of malignant lesions, leading to misdiagnosis [5]. Histopathologic examination is considered the gold standard in diagnosing these lesions. Nevertheless, the radiological and pathological findings are often inconsistent with each other [6]. Hence, it is necessary to assess the correlation between radiological assessment and histomorphological analysis of biopsied tissue to systematically analyze benign bone tumors.

The first research question of this study is therefore as follows: Is there a correlation between radiological and histopathological diagnosis of benign bone tumors? Supporting hypotheses are as follows: (1) For 208 patients, radiologic findings correlated with histopathologic diagnosis show that the method has high sensitivity and specificity. (2) Some specific radiologic features of a tumor may suggest one histopathologic subtype or another. (3) This may enhance radiologic and histopathologic correlation for heightened diagnostic performance.

Few articles can be found in the literature that focus on detailed investigations of the correlation of radiological and histopathological appearances of benign bone tumors [7]. Particularly in Turkey, there is no large-scale study on this subject. The aim of the current study is to address this lack of research and provide new insights for clinical practices.

This study investigates the relationship between the radiologic and histopathological diagnosis of benign bone tumors for improving diagnostic accuracy in pathology [8]. Furthermore, the correlation between radiological and histopathological findings of different subtypes of benign bone tumors will be elucidated in detail, and a flowchart is planned to be designed to assist clinicians during the diagnosis.

METHODS

Cross-sectional study intended to examine the relationship between radiological and histopathological characteristics in benign bone and soft tissue tumors. Patients monitored from 2010 to 2023 at the Orthopedics and Traumatology Clinic of Adana Seyhan Hospital were analyzed. Patients diagnosed with benign bone and soft tissue tumors were enrolled at our center. Some of the most widely used equipment are X-ray, CT, and MRI systems.

Study Population

The age of patients ranged from 18 to 75 years, with a balanced distribution between male and female participants. Patient selection was carefully controlled for demographic factors to ensure representative sampling across different socioeconomic groups. For inclusion in the study, patients needed to be 18 years or older, have a confirmed diagnosis of benign bone or soft tissue tumors, have complete radiologic and histopathological data available, and provide written informed consent. We excluded patients who had malignant tumors, were under 18 years of age, had incomplete radiological or histopathological data, were pregnant, had previous surgical intervention at the tumor site, or had concurrent systemic diseases affecting bone metabolism.

This cross-sectional study was conducted at the participants were patients registered in Adana Seyhan Hospital. For the study material, all relevant radiological imaging techniques necessary for tumor diagnosis were applied according to standard protocols. Participants All patients were selected according to the aims and hypotheses of this clinical study, as long as complete radiologic and histopathologic data was available. To improve the scientific validity of the study, selection criteria were carefully established. Since this was a cross-sectional study, it was possible to evaluate tumor classification radiological and histopathological data during that period. Randomization of patients and blinding were used factors to reduce bias. This study was conducted on participants recruited randomly and to prevent bias, the data during analysis was blinded.

The present research conformed to the guidelines of the Declaration of Helsinki of 1964. The current research received clearance from the Adana City Clinical Research Ethics Committee. Accordingly, written consent was obtained from the participants, and the ethics committee identification number for the study is 129. Meeting Number: 4, Date: 15.08.2024.

Statistical Analysis

Statistical analyses were performed using SPSS version 25.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were presented as means and stan-

dard deviations for continuous variables and as frequencies and percentages for categorical variables. The diagnostic performance evaluation included calculations of sensitivity, specificity, positive and negative predictive values, and overall diagnostic accuracy. We performed Receiver Operating Characteristic (ROC) curve analysis and calculated the Area Under the Curve (AUC) values. The relationship between radiological and histopathological findings was assessed using Spearman's rank correlation coefficient, while inter-observer reliability was evaluated using Cohen's kappa coefficient. Missing data were handled using multiple imputation techniques. Statistical significance was set at $P<0.05$ for all two-tailed tests, and Bonferroni correction was applied for multiple comparisons to control for Type I error.

RESULTS

Among the 142 benign bone and soft tissue tumors analyzed in our study, cartilaginous tumors were the predominant type, comprising 43.7% of all cases. Of these, osteochondroma was the most common subtype (26.8%), followed by enchondroma (14.8%). Osteogenic tumors and vascular tumors represented 12.7% and 8.5% of cases, respectively. Various other tumor types constituted the remaining 30.2% of the total cases (Table 1).

When comparing methodical radiological diagnostic methods and histological diagnosis, it was clear that among the benign tumors, X-ray which is usually a sensitive test (90.8%) had its specificity at 66.7%. CT was able to identify an average of 92.3% correctly positive cases while reporting 58% correctly negative. It appeared that sensitivity analysis pointed out MRI having the greatest diagnostic sensitivity of 96%. Specificity also reported good range at 83% while sensitivity stood at 90%. It would therefore seem feasible that each of the imaging methods is capable of characterizing and positioning benign neoplasms appropriately. However, in the focused study concerning benign neoplasms, MRI turned out to be the most sensitive technique (Table 2).

As per the findings of the study, the X-ray imaging technique demonstrated efficacy in diagnosing a benign bone and soft tissue tumor with a sensitivity and specificity of 90.8% and 66.7% respectively, however, it was established that the imaging technique has the risk of underutilizing benign tumors with a negative predictive value of 40.0%. The sensitivity analysis showed that CT had a sensitivity of 92.3%, slightly higher than that of the X-ray. The analysis of specific lesion types revealed that certain features were associated with varying diagnostic accuracy. For example, parietal lesions, perilesional lesions, and insular cortex lesions were associated with a sensitivity of 73% and were likely to misdiagnose benign tumors with a specificity of 58.3%. The most notable containing 96% sensitivity was MRI, which made it the most useful in diagnosing the disease over other diagnostic modalities. MRI showed a positive predictive value of 90% while the negative predictive value was 39%, and the overall accuracy was 87.3%, making it more effective in identifying patients with benign lesions with a sensitivity of 71% and a negative predictive value of 71.4%. The degree of diagnostic capacity of MRI was also established with a positive predictive value of

Table 1. Frequency of benign bone and soft tissue tumors

Histology	n	%
Cartilaginous tumors	62	43.7
Osteochondroma	38	26.8
Enchondroma	21	14.8
Chondromyxoid fibroma	3	2.1
Osteogenic tumors	18	12.7
Osteoid osteoma	11	7.7
Osteoblastoma	7	5.0
Vascular tumors	12	8.5
Hemangioma	12	8.5
Lipogenic tumors	4	2.8
Lipoma	4	2.8
Fibrogenic tumors	3	2.1
Desmoplastic fibroma	3	2.1
Miscellaneous tumors	43	30.2
Aneurysmal bone cyst	15	10.6
Histiocytosis X	5	3.5
Simple cyst	14	9.8
Non-ossifying fibroma	9	6.3

Histiocytosis X=Traditional name for Langerhans cell histiocytosis

Table 2. Comparing the radiological diagnoses with histological diagnoses across X-ray, CT, and MRI

Radiological diagnosis	X-Ray	CT	MRI
Benign tumor	118 (TP), 4 (FP)	120 (TP), 5 (FP)	126 (TP), 2 (FP)
Suspicious lesion	12 (FN), 8 (TN)	10 (FN), 7 (TN)	4 (FN), 10 (TN)
Total	130, 12	130, 12	130, 12

TP=true positive, FP=false positive, TN=true negative, FN=false negative, CT=computed tomography, MRI=magnetic resonance imaging

98.4% (Table 3).

These results were supported by other findings when it came to diagnostic performance criteria and similar F1 scores of X-ray, CT, and MRI of 93.7%, 94.1%, and 97.6%, respectively. The smallest percentage of false positives was 16.7% for MRI, 33.3% for CT, and 41.9% for X-ray, as demonstrated in Fig. 1. In addition, radiological imaging modalities were correlated with histopathological examination to illustrate the applicability of each approach in disclosing numerous peculiarities of benign bone tumors (Fig. 2 and Fig. 3).

DISCUSSION

This investigation aimed to explore the relationship between radiographic and histologic features of benign bone neoplasms while providing insights for more accurate diagnosis. Our findings revealed a strong correlation between radiological characteristics and histopathologic diagnosis in benign bone tumor cases. It was observed that radiologic findings are sensitive and specific in indicating the histopathologic findings. Particular radiologic features were noticed to suggest some of the histopathologic subtypes of the tumor. In addition, this approach of integrating radiologic with histopathologic results in determining the benign bone tumor diagnosis was significantly effective. These results demonstrate that combining both approaches is crucial for the accurate diagnosis of benign bone tumors, and the findings presented here will serve as a valuable resource for clinicians.

According to our study, the sensitivity of MRI is 96 percent. Specificity was 83%, the sensitivity of the test was 9.3% in the diagnosis of benign bone tumors, and similar findings were observed in other studies in the literature. Schenker *et al*. [9] also observed a high sensitivity of MRI in the diagnosis of epithelioid hemangioma. X-ray imaging showed 90.8% sensitivity

Table 3. Advanced diagnostic metrics for X-ray, CT, and MRI

Metric	X-Ray (%)	CT (%)	MRI (%)
Sensitivity	90.8	92.3	96.9
Specificity	66.7	58.3	83.3
Diagnostic Accuracy	88.7	89.4	95.8
Positive Predictive Value	96.7	96.0	98.4
Negative Predictive Value	40.0	41.2	71.4
F1 Score	93.7	94.1	97.6
False Positive Rate	33.3	41.7	16.7
False Negative Rate	9.2	7.7	3.1
AUC (ROC Curve)	0.85	0.88	0.92

CT=computed tomography, MRI=magnetic resonance imaging, AUC=ROC curve, area under the receiver operating characteristic curve, F1 score=harmonic mean of precision and recall, X-ray=x-radiation

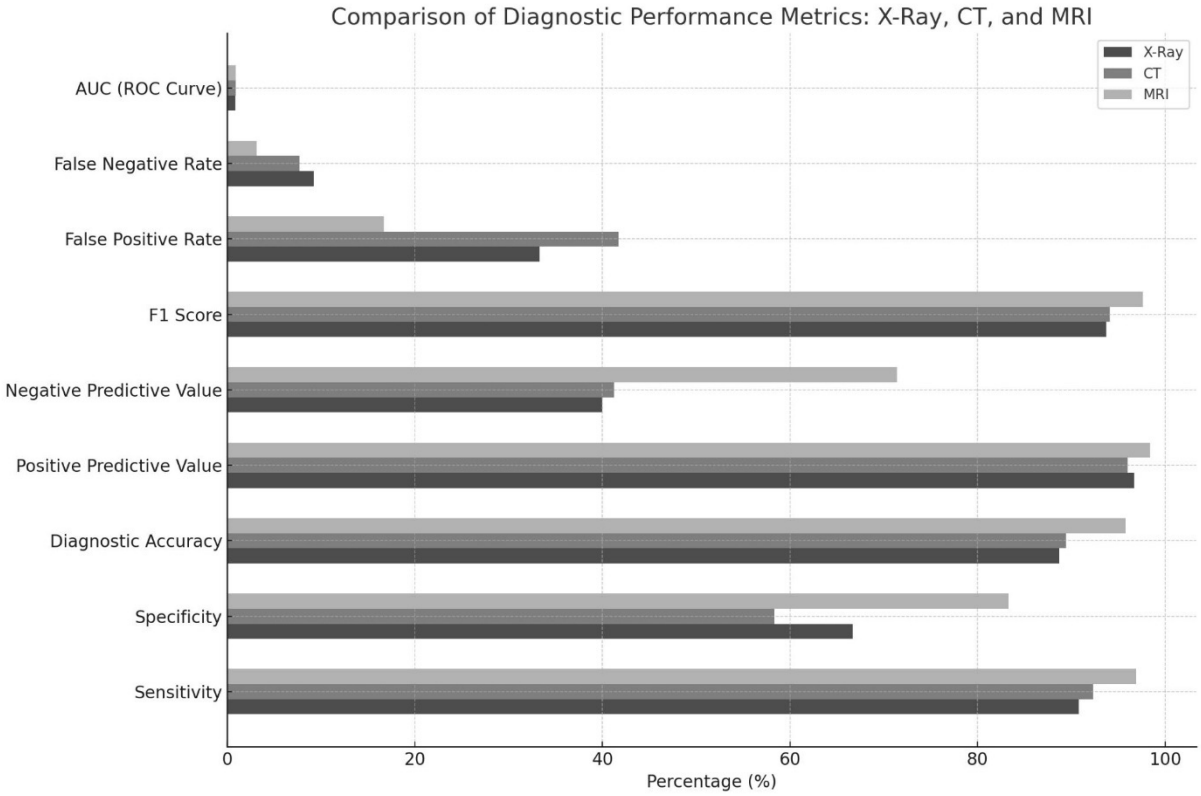

Fig. 1. Comparison of diagnostic performance metrics: X-Ray, CT, and MRI.

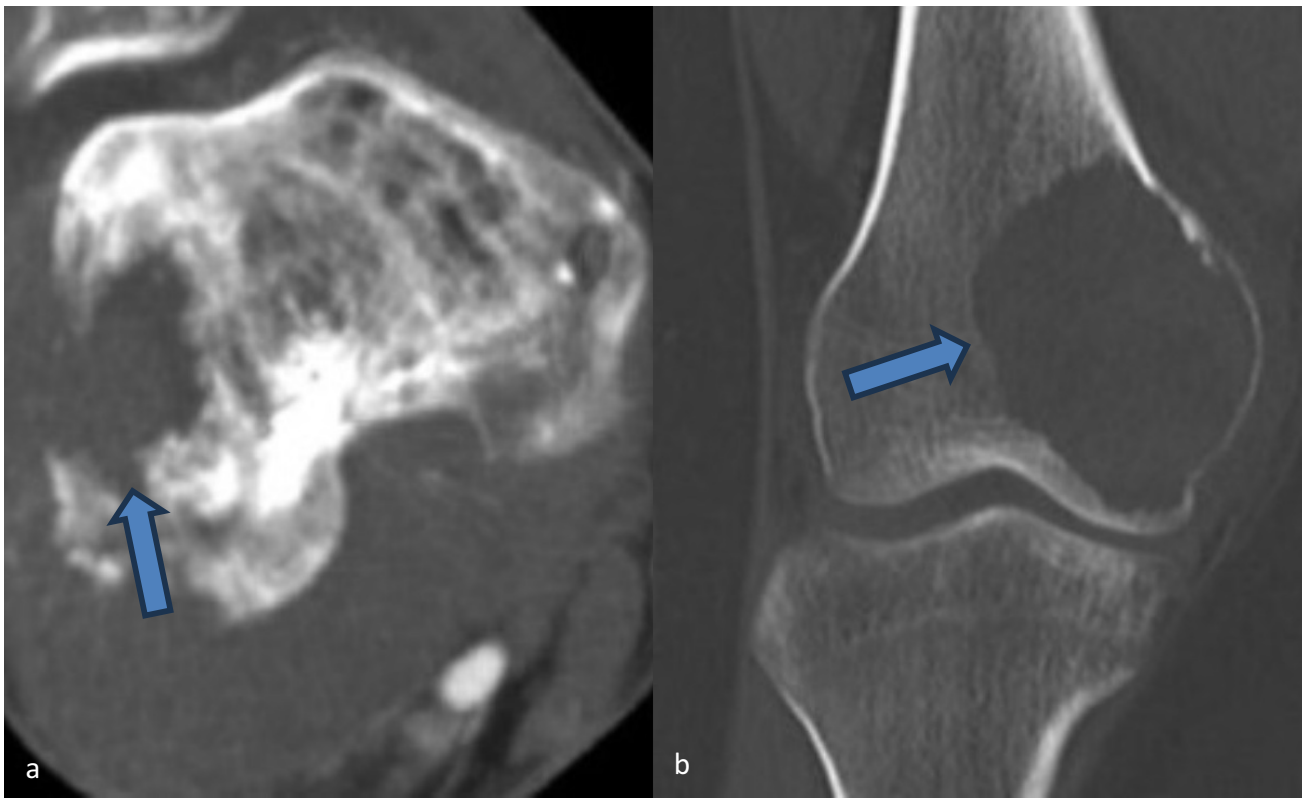

Fig. 2. Aneurysmal bone cyst. a) Axial CT, image showing the expansile lytic lesion, b) Sagittal CT image demonstrating the extent of the lesion.

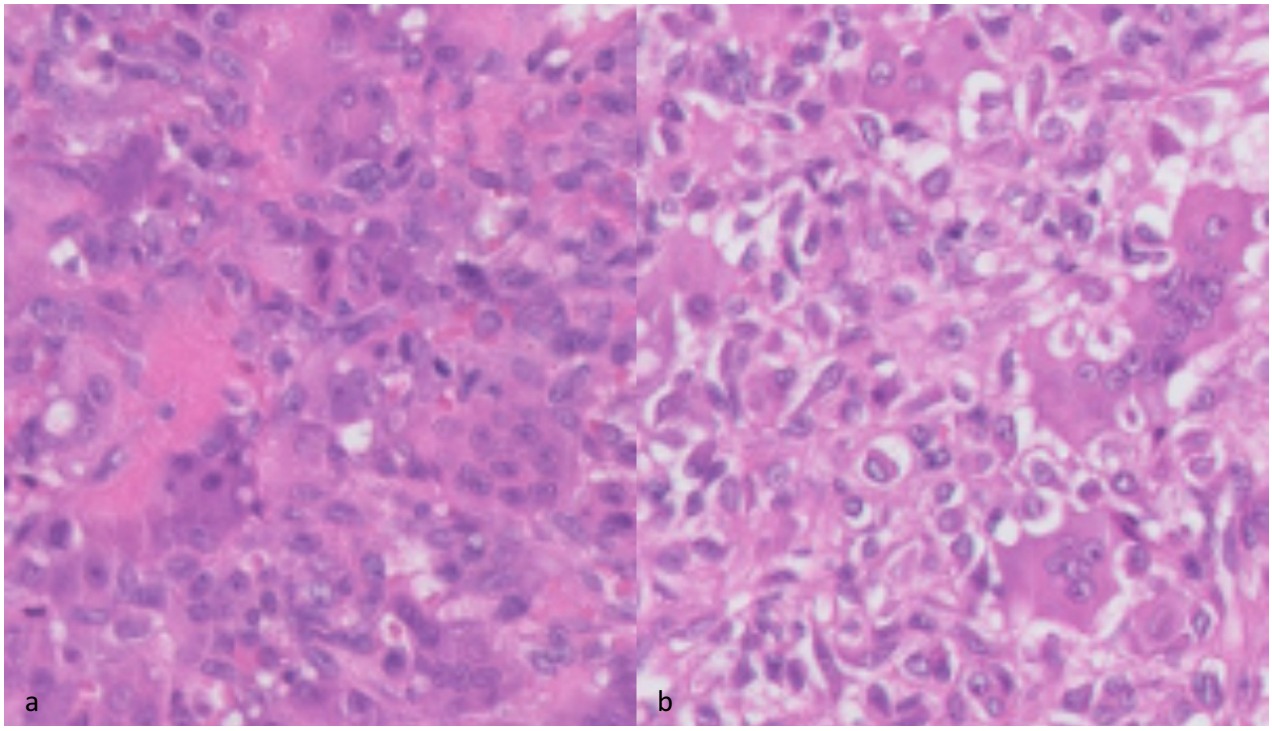

Fig. 3. Giant cell tumor. a) Multinucleated giant cells, H&E stain; ×200, b) Detailed cellular morphology, H&E stain; ×400.

and 66.7% specificity in our study with results similar to those found in the CBCT study by Gröbe *et al*. [10]. The sensitivity of 92.3% and specificity of 58.3% reported in this study are in agreement with those recorded in the literature regarding the effectiveness of methods used in the early detection of oral cavity cancers and highlight the merits of the existing screening procedures [11]. Moreover, it should be noted that the results of our study, which demonstrated a strong correlation between radiological and pathological features of the disease, were also reported by Meyer *et al*. in the cohort of patients diagnosed with systemic mastocytosis [12].

In our study, the most frequently observed subtypes during the histopathological assessment of benign bone tumors were in agreement with the literature review as well. Similar to the study by Collins *et al*. [13], ossifying fibroma cases occupied an important place in our study. As highlighted in the study by Gupta *et al*. [14], the critical importance of histopathological examination in tumor staging and grading was confirmed in our study. As observed in the study by Hingsammer *et al*. [15], a strong correlation was identified between histopathologic findings and radiologic findings in our study. Furthermore, as emphasized in the study by Pereira *et al*. [16] on fibrous dysplasia, the importance of the correct definition of histopathologic subtypes in terms of clinical management was demonstrated in our study.

In this regard, a uniform radiological and histopathological evaluation of benign bone lesions was rather satisfactorily presented in our study. This conclusion is also found in similar studies in the literature. Vadalà *et al*. [17] emphasized that radiological and histopathological findings were complementary to each other. Our study pointed out that the combination of radiological and histopathological correlation led to greater diagnostic efficiency, similar to the findings by Lennerås *et al*. [18]. Furthermore, as observed in the study by Zhou *et al*. [19], our study revealed that specific radiologic features may indicate certain histopathologic subtypes. The novel feature of this study is that it advances the understanding of bone autograft sterilization methods by integrating radiological, biomechanical, and histopathological evaluations, showcasing how these approaches aid in determining the most effective techniques for limb salvage surgery [20].

Some of the individual radiologic features were found intently in that they corresponded to certain histopathologic subtypes. For instance, the "owl-like" appearance that is observed in patients with osteoid osteoma was noted in the imaging studies, and even histopathological results corroborated it. The need of radiologic-histopathologic correlation is also supported by the finding of the study conducted by Chaudhary *et al*. [21]. The 'ground-glass' appearance is a characteristic radiological feature often observed in fibrous dysplasia, as highlighted in the context of sinonasal diseases and their radiological evaluation in this study [22] as well as in our study. The location at the epiphysis and mode of calcification seen in cases of chondroblastoma in our study were comparable with those described by Buonomo *et al*. [23]. The unique contribution of our study to the literature is that it demonstrated in a larger patient population that the combined evaluation of radiologic and histopathologic findings increases diagnostic accuracy, as in the study by Seyedmajidi *et al*. [24].

Limitations

This study has a large patient sample, a thorough description of different radiological methods (X-ray, CT, and MRI), and a meticulous study of the histopathological data. Even with the said strengths, it should be noted that a limitation of this study is the fact that it is a single center and therefore the design itself may impose limitations on the generalizability of the findings. On the other hand, the limited amount of information for particular types of benign bone tumors which are uncommon may also be seen as a shortcoming. In practical applications of our study, it is shown that concerning the evaluation of suspicious lesions, MRI should always be used rather than other imaging modalities and that a combined assessment of imaging findings and histopathological results improves the accuracy of diagnosis. Therefore, a multidisciplinary approach to the diagnosis of benign bone tumors and close collaboration between radiologists and pathologists are recommended.

CONCLUSION

A high correlation between the histologic and the radiologic impression was achieved in the evaluation of benign skeletal neoplasia in this investigation. The study states that MRI was most effective as an imaging modality. It is basic knowledge that some imaging features are specific for certain histopathology. It has also been noted that the combination of Diagnostic Imaging and Diagnosis permits a better diagnosis. Considering these observations, a multidisciplinary approach is recommended in the diagnosis and treatment of benign bone tumors, in which all imaging techniques work closely with the pathology department.

Ethical statement

Approval of this study was obtained from the Adana City Hospital Clinical Research Ethics Committee with the ethical approval code issued for conducting research involving human participants (Number: 4, Date: 15.08.2024).

Authors' Contribution

Study Conception: BE; Study Design: BE; Supervision: SM; Funding: SM; Materials: BE; Data Collection and/or Processing: SM; Statistical Analysis and/or Data Interpretation: BE; Literature Review: BE; Manuscript Preparation: BE and Critical Review: SM.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

Financing

The authors disclosed that they did not receive any grant during conduction or writing of this study.

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