Int J Burn Trauma 2021;11(3):207-219
www.IJBT.org /ISSN:2160-2026/IJBT0133655

Original Article

Challenges in management of benign bone tumours complicated by pathological fracture in paediatric population

Yasir Salam Siddiqui, Mazhar Abbas, Julfiqar Muhammad, Mohd Khalid A Sherwani, Mohammad Jesan Khan, Akash Yadav

Department of Orthopaedic Surgery, J. N. Medical College, Faculty of Medicine, A.M.U., Aligarh, India

Received March 29, 2021; Accepted June 1, 2021; Epub June 15, 2021; Published June 30, 2021

Abstract: Background: Optimum treatment of pathological fractures following benign bone tumours in paediatric population is controversial. The usual difficulties encountered while dealing such cases is to establish a correct pre-operative diagnosis and to choose between conservative vs operative management. The aim of the work is to highlight the difficult aspects of diagnosis and management of pathological fractures following benign bone tumours in paediatric population. Methods: All paediatric patients (<18 years) with pathological fractures following benign bone tumours were included. Pathological fractures due to infection, metabolic bone diseases and malignant bone tumours were excluded. Initial pre-operative diagnosis was based on clinico-radiological characteristics of the tumour and FNAC/needle biopsy, while final diagnosis was confirmed with post-operative histology. Primary outcome measure was determination of any disparity between pre-operative diagnosis and final post-operative histological diagnosis and the need of a separate open biopsy procedure for establishing the exact nature of lesion. Secondary outcome measures were determination of complications following surgery, functional grade and any recurrence at latest follow-up at 3 years. Results: Out of 13 patients enrolled for the study, twelve patients met the inclusion criteria. Female to male quotient was 3:1, with average age of 12.17 years. We were able to make correct pre-operative diagnosis in 10 patients (83.3%) with systematic clinico-radiological analysis and carefully performed FNAC/needle biopsy. Disparity between pre-operative and final post-operative diagnosis was seen in two patients. In one of these two patients, initial pre-operative diagnosis was fibrous dysplasia, which turned out to be ossifying fibroma on final post-operative biopsy. While the other patient required an open biopsy to establish the nature of underlying pathology, as the pre-op histological evaluation revealed equivocal nature of bone lesion. Secondary outcome measures showed superficial infection in one, coxa vara in one, limb length discrepancy in 2 and fibular graft donor site morbidity in two. None of the patient had developed recurrence. All patients had complete healing of the fracture and lesion. Conclusion: A thorough clinico-radiological analysis and carefully performed FNAC/needle biopsy can establish a correct pre-operative diagnosis in majority of patients with benign bone tumours complicated by pathological fracture. This approach will avoid preventable delay in the definitive treatment of such patients, and also preclude the need of a separate operation prior to definitive management. In sight of the findings of our study along with existing literature we propose for definitive treatment in straight-forward cases and pre-treatment biopsy in cases with inconclusive FNAC/needle biopsy results and lesions with suspicion of malignancy. Proper diagnostic evaluation and differentiation of benign pathological fractures from malignant counterparts followed by extended curettage or excision of lesion and biological reconstruction with or without osteosynthesis represents a feasible approach for managing such fractures.

Keywords: Benign bone tumours, pathological fracture, paediatric population, fine needle aspiration cytology (FNAC), biopsy

Introduction

Benign bone tumours are frequently complicated by pathological fracture in paediatric population, and sometimes the occurrence of pathological fracture is the initial presenting symptom. Simple bone cyst (SBC), aneurysmal bone cyst (ABC), non-ossifying fibroma (NOF), ossifying fibroma and fibrous dysplasia are the common childhood benign bone tumours compli-

cated by pathological fracture [1-3]. The identification of pathological fracture is straightforward. However, there are some snags in diagnosis that the orthopaedician should essentially anticipate to avoid failure of diagnosing the pathological fracture and its optimal treatment. The detection of a pathological fracture can be a reason for apprehension as it might be the chief presentation of a primary bone disease [4]. Defining the primary bone disease is indispensable for sorting out the precise treatment in paediatric benign bone tumours complicated with pathological fractures. The history, clinical examination, radiographical and lab work-up remain instrumental in defining the possible pathology [3]. Site of tumour and its radiographical depiction are the key factors for accurately diagnosing benign bone tumour [5]. The laboratory work-up is of less significance in primary bone tumour diagnosis. However, they aid in differentiation from metabolic bone diseases and infections [6]. The optimum treatment of pathological fractures following benign bone tumours in paediatric population remains controversial. The usual difficulties encountered while dealing such cases is to establish a correct pre-operative diagnosis and to choose between conservative vs operative management. Moreover, the indications for operative treatment, methods of clearing the tumour, methods of biological reconstruction and stabilization with or without osteosynthesis and establishment of definite histological diagnosis prior to or following definite treatment is not undoubtedly distinct [1, 2]. Since the literature is scarce on the management of benign bone tumours associated with pathological fractures, the current study describes practical problems and provides a systematic approach to deal with such lesions.

Aims & objectives

The main aim of the present work is to highlight the difficult aspects of diagnosis and management (concerns related to diagnostic work-up, differentiation from malignant bone tumours and treatment) of pathological fractures following benign bone tumours in paediatric population.

Methods

Study design with Inclusion and exclusion criteria

This is a prospective study of the difficult aspects of diagnosis and management of benign bone tumours complicated by pathological fracture in paediatric population. The duration of study was two years extending from Jan., 2014 to Dec., 2016. The work was permitted by the official ethical board of our institution (D. No. 310/FM/IEC). Informed consent was taken from all participants. All paediatric patients (<18 years) with clinico-radiological diagnosis of pathological fractures following benign bone tumours were included in the study. Pathological fractures due to infection, metabolic bone disease, and malignant bone tumours were excluded.

Management protocol

During the study period, 13 patients were enrolled for treatment of pathological fractures with clinico-radiological diagnosis of benign bone tumour. All patients were investigated for determining the underlying diagnosis (including histological diagnosis). Antero-posterior and lateral radiographs of the involved extremity and the plain radiograph of the chest were done. Routine blood investigations including blood counts with general blood picture, blood urea nitrogen, liver function test, alkaline phosphatase, serum sodium, potassium and calcium were done. MRI of the involved extremity was done when clinical features were suggestive of some malignancy, and was not routinely done in all cases due to economic constraints. Pre-operative histological evaluation was done by utilizing fine needle aspiration cytology (FNAC) or needle biopsy. Care was taken to take sample from the lesion, away from the fracture haematoma. If the result of FNAC or needle biopsy was inconclusive or equivocal, or there is any suspicion of underlying malignant lesion, then open biopsy was done to establish the histological diagnosis, prior to definitive treatment. Our main goal of getting pre-op histological evaluation before any definitive management, was to ascertain the benign nature of lesion or at least to rule out the malignant nature of lesion, so as to avoid inappropriate treatment of malignant lesions in paediatric population. In nutshell initial pre-operative diagnosis was based on clinico-radiological characteristics of the tumour and FNAC/needle biopsy, while final diagnosis was confirmed with post-operative histological examination of the tumour (**Table 1**).

Pre-operative appraisal of the patient encompassed determination of age, gender, type of

Table 1. Illustrating age/sex, mode of injury (trivial trauma in all), anatomical site of fracture, type of fracture, pre-fracture functional grade, Pre-operative diagnosis, Final histological diagnosis, management and outcome of pathological fractures following benign bone tumours in our series

Case No.	Age (Years) & Sex	Anatomical site of fracture	Type of fracture	Pre-fracture functional grade	Pre-operative diagnosis	Final histological diagnosis	Management	Outcome
1	15/M	Proximal humerus	Complete	Pain & swelling	SBC	SBC	Extended curettage+Fibula strut graft	Lesion healed at 9 months
2	12/F	Proximal femur	Complete	Pain	SBC	SBC	Extended curettage+Fibula strut graft+Osteosynthesis	Lesion healed at 6 months
3	11/F	Proximal humerus	Complete	Pain	SBC	SBC	Extended curettage+Fibula strut graft	Lesion healed at 8 months
4	12/F	Proximal femur	Complete	Pain	ABC	ABC	Extended curettage+Fibula strut graft+Osteosynthesis	Lesion healed at 10 months
5	4/F	Proximal femur	Complete	Pain	ABC	ABC	Extended curettage+Osteosynthesis	Lesion healed at 6 months, Developed Coxa vara & Limb length discrepancy
6	9/M	Distal tibia	Complete	Pain & swelling	ABC	ABC	Extended curettage+Tricortical iliac crest bone graft	Lesion healed at 8 months
7	11/F	Proximal Humerus	Complete	Pain	ABC	ABC	Extended curettage+Fibula strut graft	Lesion healed at 10 months
8	17/F	Proximal femur	Complete	Pain & swelling	Fibrous dysplasia	Fibrous dysplasia	Extended curettage+Cancellous graft+Osteosynthesis	Lesion healed at 16 months
9	13/F	Proximal femur	Microfracture	Asymptomatic	Fibrous dysplasia	Fibrous dysplasia	Extended curettage+Tricortical iliac crest bone graft+Osteosynthesis	Lesion healed at 13 months
10	9/M	Distal Tibia	Microfracture	Pain & swelling	Fibrous dysplasia	Fibrous dysplasia	Extended curettage+Tricortical iliac crest bone graft	Lesion healed at 13 months
11	16/F	Mid shaft tibia	Microfracture	Pain & swelling	Fibrous dysplasia	Ossifying fibroma	Excision+Fibula strut graft+Cancellous graft+Osteosynthesis	Lesion healed at 18 months, Developed stress fracture of grafted fibula
12	17/F	Distal third femur	Complete	Pain	Pathological fracture	Non ossifying fibroma	Open biopsy+Curettage+External fixator	Lesion healed at 7 months
Total No. of patients with healed lesions								12

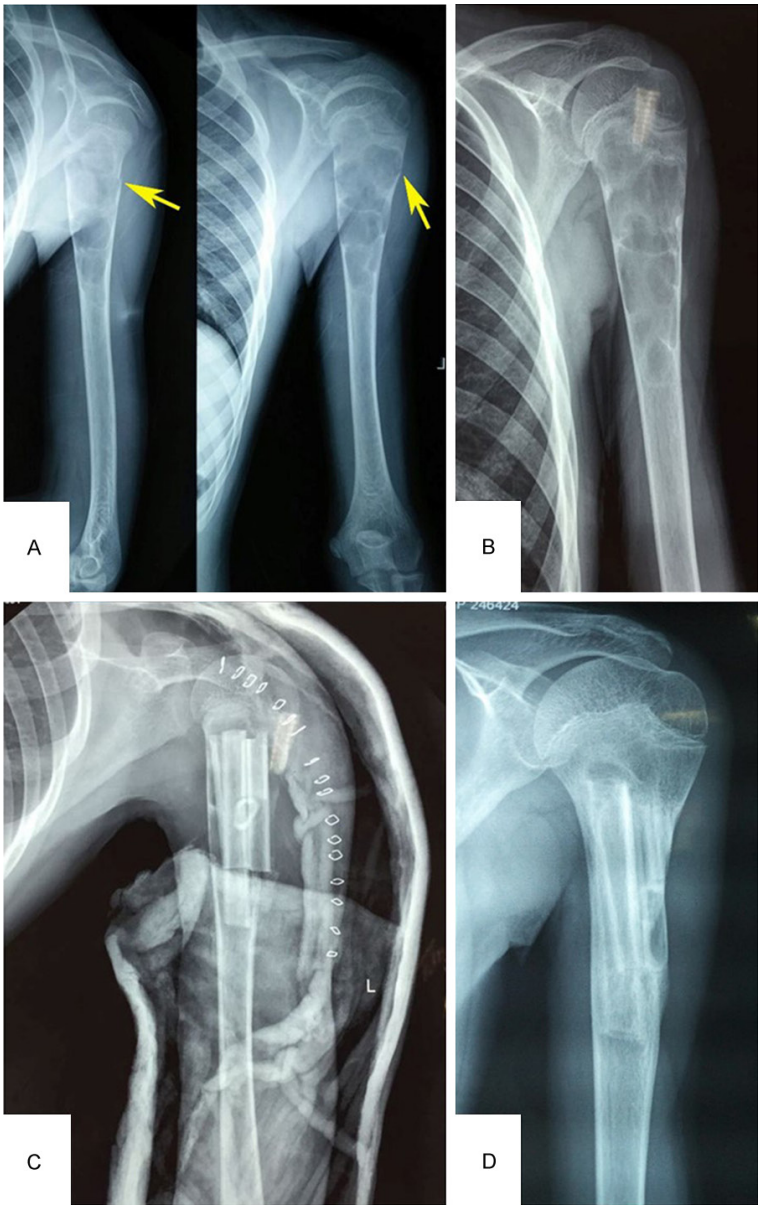

Figure 1. A: Plain radiograph of patient (case-1) showing undisplaced fracture of proximal humerus (arrow heads) with a geographic pattern of osteolysis of metaphyseo-diaphyseal region. Also note the absence of periosteal reaction, soft tissue infiltration & new bone formation. Clinico-radiologically a diagnosis of simple bone cyst with pathological fracture was made. Initially patient was managed in arm sling. B: Plain radiograph of the patient showing healed fracture. The lesion persisted & was subjected to extended curettage & biological reconstruction with fibula. C: Immediate post-operative radiograph of the patient showing curetted lesion with fibular strut graft in situ. D: Plain radiograph of the patient showing healed lesion and incorporated fibular grafts.

injury, anatomic location of the tumour, fracture classification (micro-fracture or complete fracture) [3], pre-fracture functional grade (**Table 1**). Initially undisplaced fractures were managed conservatively (sling, cast, or traction) till healing of fracture (**Figure 1A** and **1B**). Finally patients were treated with extended curettage or excision of lesion, followed by filling of the cavity or reconstruction of defect by fibular autograft and iliac crest cancellous bone graft with or without osteosynthesis (**Figures 1C**, **2B** and **3B**). Patients were regularly followed up in outpatient department at interval of 2 months for the first 12 months, 3 monthly for the next 12 months, then at 6 months interval thereafter. Clinico-radiological assessment was performed at each follow-up visit. Mean follow-up was 38 months (range = 36-40 months).

Outcome measures

Our primary outcome measure was determination of any disparity, between pre-operative diagnosis of the tumour through systematic approach and final post-operative histological diagnosis and the need of a separate open biopsy procedure for establishing the exact nature of lesion. Secondary outcome measures were determination of complications following surgery, functional grade and any recurrence at latest follow-up of 3 years (**Table 2**).

Statistical analysis

All statistical analysis was done by Microsoft office 2010. The calculation of averages and standard deviation was done using data analysis tool. We also calculated 95% confidence interval (CI) for correct diagnostic interpretation of our study protocol. The confidence interval was calculated via

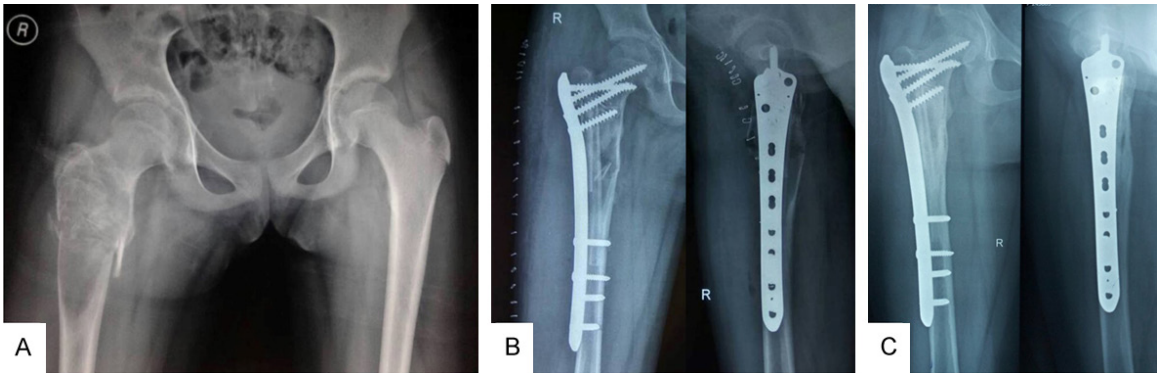

Figure 2. A: Plain radiograph of patient (case-2) showing fracture of proximal femur with geographic pattern of osteolysis. Clinico-radiologically a diagnosis of simple bone cyst with pathological fracture was made. The patient was subjected to extended curettage with biological reconstruction using fibula & fixation with plate. B: Immediate post-operative radiograph of the patient showing curetted lesion with fibular strut grafts augmented with plate osteosynthesis. C: Plain radiograph of the patient showing healed fracture & lesion with complete incorporation of fibular grafts.

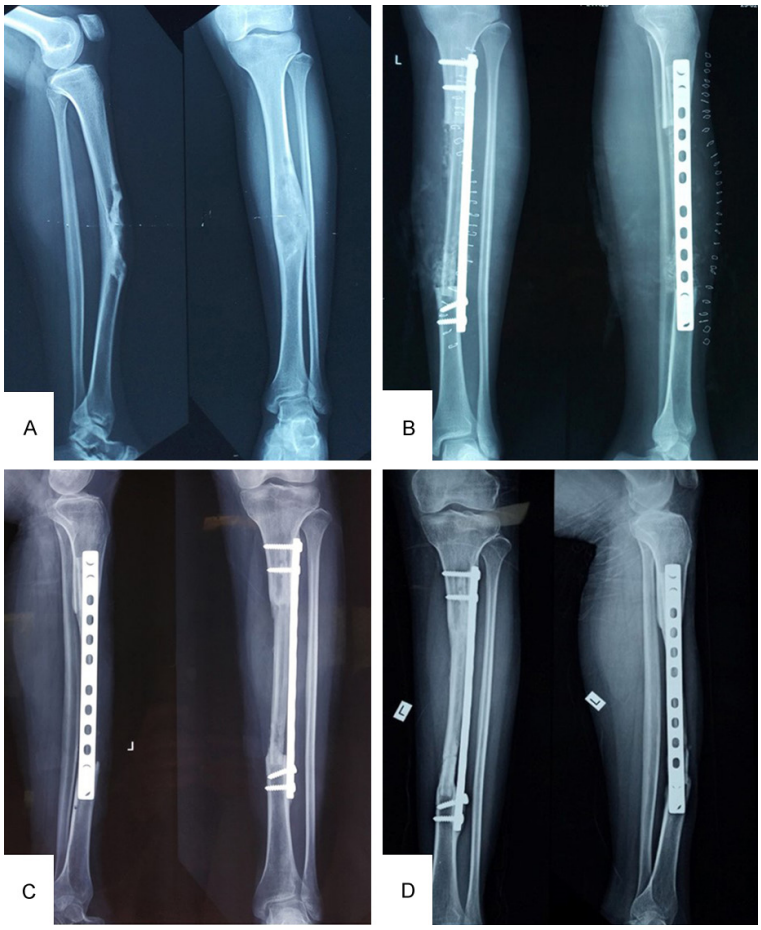

Figure 3. A: Plain radiograph of patient (case 11) showing multiple well defined lucencies in mid diaphysis of tibia separated by sclerotic borders with thickening of posterior cortex and anterolateral bowing of tibia (evidence of healing of stress fractures). Patient presented with minor trauma, following which she was not able to bear weight on the extremity. Clinico-radiologically a diagnosis of fibrous dysplasia with pathological fracture was made. The FNAC was suggestive of fibrous dysplasia. The lesion was subjected to resection and biological reconstruction with fibula. B: Immediate post-operative radiograph of the patient showing excised diseased segment of tibia with biological reconstruction using fibular strut graft augmented with plate osteosynthesis. Also note iliac crest cancellous bone graft at the both ends. The excised segment of tibia on final biopsy report confirmed the lesion to be ossifying fibroma and not fibrous dysplasia. C: Plain radiograph of the patient showing gradual incorporation with hypertrophy of the grafted fibula. D: Plain radiograph of the patient showing healing stress fracture of grafted fibula with incorporation and hypertrophy of the grafted fibula.

Agresti-Coull (adjusted Wald) interval [7].

Results

Study population and demographic characteristics

Out of 13 patients registered for treatment of pathological fractures with clinico-radiological diagnosis of benign bone tumour, 12 patients met the inclusion criteria. One patient was excluded because of underlying pathology was other than benign bone tumour. Out

Table 2. Post-operative complications

Complications	Number of patients
Superficial infection	1
Deep infection	0
Recurrence	0
Limb length discrepancy (lower limbs)	2
Coxa vara	1
Peri-implant fracture	0
Fibular Graft donor site morbidity (Lateral leg discomfort & numbness)	2
Common peroneal nerve palsy	0
Stress fracture of grafted fibula	1
Total No. of complications	7

Table 3. Relative frequencies of benign bone tumours in our series of pathological fractures

Histology	No. of cases	% of cases
Simple bone cyst	3	25
Aneurysmal bone cyst	4	33.34
Fibrous dysplasia	3	25
Ossifying fibroma	1	8.33
Non ossifying fibroma (Metaphyseal fibrous defect)	1	8.33
Total	12	100

of 12 patients, female to male quotient was 3:1 (9 females with 3 males), with age ranging from 4 to 17 years (mean age of 12.17 years). Among the 12 patients, final histology of bony lesion comprises of 3 cases of simple bone cysts (25%), 4 cases of aneurysmal bone cysts (33.34%), 3 cases of fibrous dysplasia (25%) and 1 case each of ossifying fibroma and non-ossifying fibroma (8.33%; **Table 3**). Mean follow-up was 38 months (range = 36-40 months). The utmost shared location of pathological fracture was the proximal femur in 5 (41.67%) patients, proximal humerus in 3 (25%), tibia in 3 patients (25%) and lower third femur in 1 patient (8.33%). Three fractures were classified as microfractures (ossifying fibroma midshaft tibia, fibrous dysplasia proximal femur and fibrous dysplasia distal tibia) and rest 9 were complete fractures, as described by Ortiz [3].

Rate of disparity between pre-operative and post-operative diagnosis

We were able to make correct pre-operative diagnosis in 83.3% (10/12; 95% CI = 54-96.50) with systematic clinico-radiological analysis and carefully performed FNAC/needle biopsy. Disparity between pre-operative and final post-operative diagnosis was seen in two patients (case-11 and 12). In one, initial pre-operative diagnosis was fibrous dysplasia, which turned out be ossifying fibroma on final post-operative biopsy (case-11). This patient presented with minor trauma, following which she was unable to bear weight on the extremity. Plain radiograph of patient revealed multiple well defined lucencies in mid diaphysis of tibia separated by sclerotic borders with thickening of posterior cortex and anterolateral bowing of tibia (evidence of healing of stress fractures, **Figure 3A**). Clinico-radiologically a diagnosis of fibrous dysplasia with pathological fracture was made. The pre-op histological evaluation was also indicative of fibrous dysplasia. The lesion was subjected to resection and biological reconstruction with fibula. Post-operative biopsy revealed ossifying fibroma. Clinico-radiologically it is difficult to differentiate ossifying fibroma from monostotic fibrous dysplasia as in our case. In another patient we have to do an open biopsy to establish the underlying diagnosis of the nature of lesion (case-12, **Figure 4A-C**), as result of pre-op histological evaluation was equivocal.

Secondary outcome measures showed superficial infection in one, coxa vara in one, limb length discrepancy (lower limbs) in 2, fibular graft donor site morbidity (lateral leg discomfort & numbness) in two. We have not encountered any case of common peroneal nerve palsy and peri-implant fracture (**Table 2**). None of

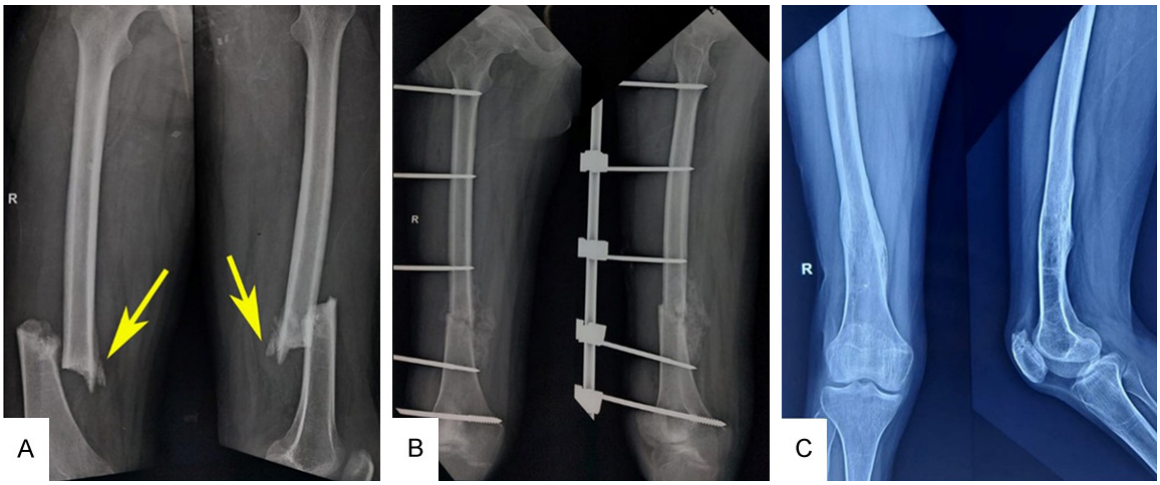

Figure 4. A: Plain radiograph of patient (case-12) showing displaced fracture of distal third of femur with sclerosis and thickening of postero-medial cortex of proximal fragment (arrow heads). History of trivial trauma raised suspicion of pathological fracture. Her MRI was also unable to reveal the nature of pathological lesion. Cytology report was suspicious of some underlying malignancy. Open biopsy and stabilization of fracture was done with external fixator. Her final biopsy report revealed non-ossifying fibroma. B: Plain radiograph of the patient at 3 weeks of surgery showed exuberant callus and uniting fracture. Presence of callus and uniting fracture prevented us from revision nailing as a definitive procedure in this patient. C: Plain radiograph of the patient showing healed fracture and the lesion.

the patient had developed recurrence at latest follow-up (36 months to 40 months). Clinico-radiologically, all patients had complete healing of the fracture and lesion (**Figures 1D**, **2C**, **3C** and **4C**). Bone grafts were fully incorporated into the recipient site within 6 to 18 months. One of the two patients with limb length discrepancy was managed with shoe raise alone. The other patient with limb length discrepancy also has decreased neck shaft angle, for which valgus osteotomy was offered to the patient (case-5, ABC proximal femur). Patient and her attendants declined for corrective osteotomy. One patient with ossifying fibroma of midshaft tibia (case-11), developed stress fracture of grafted fibula which responded to conservative treatment. All our patients returned to their normal activity except one patient with ossifying fibroma of tibia, who is on calliper to protect the grafted fibula.

Discussion

The methodological problems faced during management of paediatric benign bone tumours complicated by pathological fracture were classified as follows-Concerns related to:

1) diagnostic work-up.

2) differentiation from malignant bone tumours.

3) treatment.

1) Concerns related to diagnostic work-up: The history, clinical examination, radiographical and lab work-up remain instrumental in defining the possible pathology. Orthopaedician should have high index of suspicion for occurrence of pathological fracture in a paediatric patient when history suggests a fracture following minor injury or when the radiological examination of the child suggests an unconventional location and/or pattern of the fracture [3]. Classically, a pathological fracture is defined as a fracture occurring with minor injury that characteristically would not have resulted the kind of fracture perceived. In paediatric population, majority of pathological fractures are attributed to benign bone tumours [4]. While, pathological fractures owing to malignant bone neoplasms are infrequent, with a reported rate of 5% to 13% in paediatric osteosarcomas [8, 9]. As reported in the literature, the first essential indicator of neoplastic bone pathology is pain, which was also supported by the findings of our series (n = 11 patients; 91.66%) [3]. Similarly, Erol B [10] has also reported pain and limp as the most common presenting symptom while studying the proximal femoral benign bone lesions in children. Hence, enquiring about the presence of pain

prior to fracture helps in establishing the nature of underlying disease. Pain with activity suggests a benign tumour whereas persistent, progressive rest pains including the night pains are features of malignant tumour. None of the patient in our case series complaint of persistent, progressive rest pains including the night pains. Hence the role of good history taking and clinical examination cannot be overemphasized. Site of tumour and its classical radiological depiction are the key factors for accurately diagnosing benign bone tumour [5], as was evident in our series (**Figures 1A** and **2A**). However, full length orthogonal X-rays of the fractured bone should be ordered and carefully evaluated for any pathology, such as osteolysis, pattern of osteolysis (geographic, moth eaten or permeative), osteosclerosis, soft tissue densities, presence of an expansile bone lesion or any sub-periosteal new bone formation in response to periosteal elevation and any metaphyseal or epiphyseal changes to avoid pitfalls in making diagnosis of pathological fracture [4]. The radiological evaluation also assists to define if the primary bone pathology is limited to a solitary or multiple bones or global (involving whole skeletal system). Dumitriu [11] while studying pitfalls in the diagnosis of common benign bone tumours in children stressed on that benign bone tumours in children may have atypical radiological presentations and some normal variants may be frequently misinterpreted as tumours. Nevertheless, plain X-ray is the main imaging tool for focal bone lesions and additional imaging techniques complementary to X-ray are most often not compulsory. In nut-shell, clinicoradiological evaluation of bone tumour is indicative of the possible diagnosis. However, for the definitive diagnosis, tissue study is indispensable [12]. Albeit some tumours have overlapping clinico-radiological features, which may lead to error in making correct diagnosis, as was observed in our patient of ossifying fibroma (case-11). Therefore, it is vital to do a tissue biopsy to certain the pathological nature of fracture and to delineate the exact aetiology of bone neoplasm, prior to management planning [3, 4]. The lab work-up is of less significance in primary bone tumour diagnosis. However, they aid in differentiation from metabolic bone diseases and infections [6].

2) Concerns related to differentiation from malignant tumours: The difficult aspects of management include differentiation from malignant bone tumours. Though, pathological fractures owing to malignant bone neoplasms are infrequent in paediatric population. Nevertheless, probability of malignant lesion must be kept in mind. Ji Hyun Bae [13], while studying radiological differentiating features between benign and malignant bone tumours with an associated pathological fracture stressed on ill-defined tumour margin, concomitant extra-osseous soft tissue mass, the homogeneous enhancement pattern, and the presence of a displaced fracture were suggestive of malignant nature of bone lesion. Presence of the above radiological features warrants tissue biopsy (preferably open) before definitive treatment, as we have done in case-12. However, literature also supports a thorough clinico-radiological appraisal can identify bone tumours [5], yet some lesions do have an overlapping presentation (osteolytic type of osteosarcoma vs ABC) [14, 15]. Subsequent to clinico-radiological and lab work-up, it is vital to do a tissue biopsy, especially in cases with doubtful diagnosis, probable benign destructive bone lesions or malignant ones. Pre-op histological evaluation of case-12 showed presence of some atypical cells. Our pathologist suggested an open biopsy for making a final diagnosis. Hence open biopsy was done with temporary stabilization of fracture with external fixator (case-12, **Figure 4A-C**). Jackson [2] suggested that confirmatory tissue diagnosis should precede surgical stabilization of a pathological fracture. Undoubtedly, such approach will circumvent the devastating complications of inapt treatment of malignant lesions in paediatric population. However this strategy is by far not exclusively feasible in developing countries where there are issues of availability of OT's, economic constraints and long waiting list of patients. To counteract these problems we have done definitive treatment in straight-forward cases (diagnosed with systematic clinico-radiological evaluation + FNAC/needle biopsy) and in cases with inconclusive or equivocal results, or if there is any suspicion of underlying malignant lesion, then open biopsy was done to establish the histological diagnosis. A thorough clinico-radiological analysis and carefully performed FNAC/needle biopsy established a correct pre-operative diagnosis in 83.3% of our patients. This systematic approach avoided preventable delay in the definitive treatment of these patients. Moreover, a

separate surgery for establishing the histological diagnosis was not required. Comparable to our study, Erol B [10] has established a correct diagnosis in 93.5% patients while studying benign bone lesions of proximal femur. Devi [16] in their study also established that conclusive FNAC report of a musculoskeletal lesion can be firmly reliable for scheduling definite treatment. Nevertheless, ambiguous or insufficient sample warrants additional investigative measures to establish final diagnosis. Furthermore Canavese [4] also advocates that once it is highly likely that the lesion is benign, the biopsy can be performed concurrently, as the lesion responsible for the pathological fracture is being treated. Erol B [10], also stressed upon the pre-operative imaging studies often support the typical diagnoses of benign cystic lesions and non-ossifying fibromas in children. He further added that intraoperative findings of the lesion and frozen section are enough to make decision and proceed with definitive surgical management and thus a separate biopsy procedure usually is not essential, apart from for rare cases of aggressive aneurysmal bone cysts imitating a malignant tumor. While obtaining biopsy from a pathological fracture, care must be taken not to take the tissue sample from the fracture haematoma or callus, else it might clue to wrong diagnosis and its dreadful consequences.

3) Concerns related to treatment: The optimum treatment of pathological fractures following benign bone tumours in paediatric population remains controversial weather to go for conservative or operative treatment. Moreover, the indications for operative treatment, methods of clearing the tumour, methods of biological reconstruction and stabilization with or without osteosynthesis and establishment of definite histological diagnosis prior to or following definite treatment is not undoubtedly distinct [1, 2]. On the basis of the clinical behaviour of lesion, Dormans [1] had laydown treatment guidelines for the optimal management of paediatric bone lesions, including the pathological fractures by grouping the lesions from group I to IV. However, the stated treatment guidelines remain ambiguous on the concern of establishment of definite histological diagnosis prior to or following definite treatment. As discussed earlier, most benign tumours can be differentiated radiologically from malignant tumours. However some tumours do have overlapping presentation [5, 14]. Tissue diagnosis dictates the optimal treatment of the tumour and fracture concern. The vital principle for prompt management of such fractures is that fixation of the fracture should not be commenced without a confirmatory tissue diagnosis and proper staging [4]. Nevertheless, literature also supports the approach of obtaining a tissue biopsy simultaneously from the benign bone lesion accountable for the pathological fracture at the time of definite treatment of the tumour and fracture concern [2-4]. Ryszard Tomaszewski [17], while studying benign lesions and pathological fractures of the proximal femur in children made pre-operative histopathologic evaluation in only 53.3% children and in the remaining 46.7% cases, histopathologic evaluation of the lesion took place during surgery, further supporting the notion that separate biopsy procedure usually is not essential. The treatment plan is varied for benign lesion with pathological fracture (cystic lesions) versus a pathological fracture owing to a malignant bone neoplasm (e.g., Ewing sarcoma). Pre-treatment tissue diagnosis is not obligatory for benign lesions. However, in case of a pathological fracture due to a malignant bone neoplasm, the treatment of primary pathology takes priority over that of the fracture, as the patient's existence can be threatened by the primary bone pathology rather than the fracture itself. Internal stabilization of the fracture in such cases can make the locoregional control of the primary malignant tumour more complex and difficult [4]. As an alternative the fractured extremity is stabilized either with casting or with external fixator, as was done in our case-12. Primary bone malignancy contributes to one in every six paediatric pathological fractures [3]. Hence, in doubtful cases of the nature of the lesion, the confirmatory tissue diagnosis should regularly be established by a pre-treatment open biopsy.

Type of treatment based on histology

Although, simple bone cyst accounts for the majority of pathological fracture in paediatric patients [2, 3, 18, 19]. However, in our study it was second in order, accounting for 25% cases (n = 4). Proximal humerus followed by the proximal femur were the common locations of pathological fracture in our series. The main aim of treatment is the healing of the fracture and cys-

tic lesion [4]. Moreover, pathological fractures around proximal femur, owing to their inherent instability and gross displacement warrants internal fixation, as we have done in our study [20]. Akin to us, Ryszard Tomaszewski [17] also recommends internal fixation of the pathological fracture using plate osteosynthesis while Erol B [10] recommends titanium elastic nails, sliding hip screws, and cancellous screws for stabilization of lesions. In our study all lesions healed, which is comparable to healing rates of Ryszard Tomaszewski [17] 86.7% and Erol [10] 90.3%.

In literature aneurysmal bone cyst (ABC) is responsible for about one-third of cases of the pathological fracture. However, in our study it was the commonest lesion responsible for pathological fracture (33.34%). Most pathologic fractures occur in the active phase of ABC [21]. Literature supports that the tissue diagnosis of cystic lesions is challenging following pathological fracture, owing to the presence of blood and its products, fibrin, reactive proliferative cells and tissues [3]. In our study proximal femur was the commonest site followed by proximal humerus and distal tibia. Management essentially conglomerates treatment of the fracture and the tumour. Surgical procedures (extended curettage, resection with reconstruction) may perhaps be obligatory, as the cyst barely heals following fracture consolidation. Augmentation with plates or intramedullary nails may be required and is dictated by the site of fracture and displacement [3, 10, 17, 19].

Fibrous Dysplasia (FD) is a benign bone lesion characterized by replacement of normal bone by fibrous tissue. Difficult aspect of diagnosis and management is to differentiate between the two forms of disease (monostotic and polyostotic) and association of the later with endocrine abnormalities, which requires additional radiological work-up and endocrine testing [3, 4, 19]. Although, pathological fractures due to FD are rare. However, stress fractures are the usual finding in regions of high stress zones especially proximal femur. We have noted 3 cases of pathological fractures (one complete and 2 microfractures). Operative treatment is warranted for widespread painful lesions [3, 4, 19, 22, 23].

Non-ossifying fibroma is a benign bone lesion that is characteristically asymptomatic [3]. It commonly involves the metaphysis, especially distal femur as was seen in our patient. Following a pathological fracture, the priority is managing the fracture. Fractures through non-ossifying fibromas have excellent healing potential, as was seen in our patient with exuberant callus formation. Ortiz [3] recommends non-operative treatment with adequate immobilization for stable fractures and surgery for unstable, displaced fractures or when the diagnosis is unclear as in our patient (case-12). We have operated the patient first to confirm the diagnosis and applied the external fixator as temporary method of stabilization owing to the inherent instability and gross displacements. We were planning for nailing following confirmation of histological diagnosis, but presence of exuberant callus and uniting fracture, prevented us from revision surgery. Subsequently fracture and the lesion healed (**Figure 4C**).

Ossifying fibroma is a rare condition usually affecting the tibia and fibula in the first two decades of life [24]. Clinico-radiologically it is difficult to differentiate it from monostotic fibrous dysplasia as in our case. In 1966 Kempson used the term “ossifying fibroma” to describe the lesion in the tibia of young children that generally resembled fibrous dysplasia [25]. Campanacci (1976) introduced the term osteofibrous dysplasia to stress the anatomic site, developmental origin, and histologic resemblance to fibrous dysplasia [26]. The most common site is the middle third of tibial shaft, as was seen in our patient, followed by the upper third and the distal third [25, 26]. Ossifying fibroma or osteofibrous dysplasia presents radiologically as a multilocular, eccentric or intracortical osteolysis with adjacent sclerotic margins in the diaphysis or metaphysis with expansion of cortex [24]. Bowing of the bone is frequent association following healing of pathological fracture, as was seen in our patient (**Figure 3A**). Due to high recurrence rates following curettage and bone grafting alone, Lee had recommended segmental extraperiosteal excision in all cases and excision and reconstruction in extensive lesions [27]. Moreover, the author stressed on danger of obstinate morbidity if left untreated and of the probable association of osteofibrous dysplasia with adamantinoma.

Selection of approach and recurrences

Selection of an appropriate approach is a prerequisite for adequate exposure of the lesion and thus comprehensive clearance of tumour tissue. For all pathological fractures an approach that provides complete exposure of the lesion and fracture so as to perform adequate clearing of lesion (curettage or excision) and biological reconstruction should be selected. Consequently, exploitation of such approaches decreases the frequency of recurrences [28]. In all our cases, appropriate approach was undertaken. No recurrences were encountered and the lesion including the fracture healed thoroughly. Ryszard Tomaszewski [17], reported a recurrence rate of 13.3%, while Erol B [10] had no case of local recurrence.

Type of biological reconstruction

Our choice for filling of the defect following tumour clearance is non-vascularized fibular strut graft due to its well established mechanical and biological properties along with ease of harvesting. It offers comparable strength to the parent bone following complete uptake, which usually requires 6 to 12 months [28, 29]. Lesions of the lower extremities especially the proximal femur due to high stress region are prone to re-fracture. Hence we prefer osteosynthesis to augment the fibular strut graft. In current study, graft integration required 6 to 18 months. One patient developed the stress fracture of grafted fibula (case-11), which responded to conservative treatment. Similar to Ryszard Tomaszewski [17], no patient had developed peri-implant fracture or non-union.

Complications

As reported in literature, tumour recurrences occur within 2 years of the primary surgery. Factors responsible for recurrences are inadequate clearance of tumour either due to underexposure of lesion or fear of iatrogenic damage to the growth plate while curetting out the lesion [30]. In our series, one patient of ABC of proximal femur developed coxa vara and limb length discrepancy (LLD) probably due to iatrogenic damage to growth plate. Although, Ryszard Tomaszewski [17] and Erol B [10] reported LLD in a tune of 13.3% and 4.8%, respectively, but had no case of iatrogenic damage to the growth plate reported in their study. Management of pathological fractures especially involving the proximal femur entails the combined technical problems of complete clearance of the tumour tissue, biological reconstruction and stabilization of fracture for uncomplicated healing of lesion and fracture. One patient developed superficial infection that responded well to the dressings and antibiotics, representing a rate of 8.33%. No patient developed deep infection. Ryszard Tomaszewski [17], reported 3.33% deep infection rate while Erol B [10] reported 1.6% superficial infection rate.

Strengths, limitations and future recommendations

Our study attempts to highlights the difficult aspects of diagnosis and management of pathological fractures following benign bone tumours in paediatric population. The strengths of the study were the inclusion of only paediatric patients, definite treatment protocol and adequate follow-up. However small sample size, heterogeneous sample and lack of comparative groups are the limitations of the present study. Based on the encouraging results of this study, we recommend studies with large homogeneous samples, to further investigate our approach for diagnosis and management of paediatric benign bone tumours complicated by pathological fracture. Such studies will aid in laying down the principles for the diagnosis and management recommendations, especially in developing countries like ours.

Conclusion

Management of pathological fractures following benign bone tumours in paediatric population represents a challenge to orthopaedic surgeon. The optimum treatment of paediatric benign bone tumours complicated by pathological fracture remains controversial. However, a thorough clinico-radiological analysis and carefully performed FNAC/needle biopsy can establish a correct pre-operative diagnosis in majority of patients. This will avoid preventable delay in the definitive treatment of such patients, and also preclude the need of a separate operation prior to definitive management. In sight of the findings of our study along with existing literature we propose for definitive treatment in straight-forward cases and pre-treatment biopsy in cases with inconclusive FNAC/needle biopsy

results and lesions with suspicion of malignancy, to balance between practical problems. Proper diagnostic evaluation and differentiation of benign pathological fractures from malignant counterparts followed by extended curettage or excision of lesion and biological reconstruction with or without osteosynthesis represents a feasible approach for managing such fractures.

Disclosure of conflict of interest

None.

Address correspondence to: Yasir Salam Siddiqui, Department of Orthopaedic Surgery, J. N. Medical College, Faculty of Medicine, A.M.U., Aligarh, Uttar Pradesh-202002, India. Tel: +919837343400; E-mail: yassu98@gmail.com

References

[1] Dormans JP and Flynn JM. Pathologic fractures associated with tumors and unique conditions of the musculoskeletal system. In: Bucholz RW, Heckman JD, Beaty JH and Kasser JR, editors. Rockwood, Green and Wilkin's Fractures. 5th edition. Philadelphia: Lippincott Williams & Wilkins; 2001. pp. 139-240.

[2] Jackson WF, Theologis TN, Gibbons CL, Mathews S and Kambouroglou G. Early management of pathological fractures in children. Injury 2007; 38: 194-200.

[3] Ortiz EJ, Isler MH, Navia JE and Canosa R. Pathologic fractures in children. Clin Orthop Relat Res 2005; 432: 116-26.

[4] Canavese F, Samba A and Rousset M. Pathological fractures in children: diagnosis and treatment options. Orthop Traumatol Surg Res 2016; 102 Suppl: S149-59.

[5] Springfield DS. Radiolucent lesions of the extremities. J Am Acad Orthop Surg 1994; 2: 306-316.

[6] Herring JA. General principles of tumor management. Tachdjian's Pediatric Orthopedics. In: Herring JA, editor. Philadelphia: WB Saunders; 2002. pp. 1897-1953.

[7] Brown LD, Cai T and Dasgupta A. Interval estimation for a binomial proportion. Statist Sci May 2001; 16: 101-133.

[8] Abudu A, Sferopoulos NK, Tillman RM, Carter SR and Grimer RJ. The surgical treatment and outcome of pathological fractures in localised osteosarcoma. J Bone Joint Surg Br 1996; 78: 694-8.

[9] Scully SP, Temple HT, O'Keefe RJ, Mankin HJ and Gebhardt M. The surgical treatmentof patients with osteosarcoma who sustain a pathologic fracture. Clin Orthop Relat Res 1996; 324: 227-32.

[10] Erol B, Topkar MO, Aydemir AN, Okay E, Caliskan E and Sofulu O. A treatment strategy for proximal femoral benign bone lesions in children and recommended surgical procedures: retrospective analysis of 62 patients. Arch Orthop Trauma Surg 2016; 136: 1051-1061.

[11] Dumitriu DI, Menten R and Clapuyt P. Pitfalls in the diagnosis of common benign bone tumours in children. Insights Imaging 2014; 5: 645-655.

[12] Galant C, Malghem J, Sibille C, Docquier PL and Delloye C. Current limitations to the histopathological diagnosis of some frequently encountered bone tumours. Acta Orthop Belg 2008; 74: 1-6.

[13] Bae JH, Lee IS, Song YS, Kim JI, Cho KH, Lee SM, Lee YH and Song JW. Bone tumors with an associated pathologic fracture: differentiation between benign and malignant status using radiologic findings. J Korean Soc Radiol 2015; 73: 240-248.

[14] Saito T, Oda Y, Kawaguchi K, Tanaka K, Matsuda S, Sakamoto A, Iwamoto Y and Tsuneyoshi M. Five year evolution of a telangiectatic osteosarcoma initially managed as an aneurismal bone cyst. Skeletal Radiol 2005; 34: 290-4.

[15] Sangle NA and Layfield LJ. Telangiectatic osteosarcoma. Arch Pathol Lab Med 2012; 136: 572-576.

[16] Devi S, Dey S and Chakrabarty PS. Role of fine needle aspiration cytology as an initial diagnostic tool in musculoskeletal tumours. Indian Journal of Medical Research and Pharmaceutical Sciences 2015; 2: 1-10.

[17] Tomaszewski R, Rutz E, Mayr J and Dajka J. Surgical treatment of benign lesions and pathologic fractures of the proximal femur in children. Arch Orthop Trauma Surg 2020; [Epub ahead of print].

[18] Kaelin AJ and MacEwen GD. Unicameral bone cysts: natural history and the risk offracture. Int Orthop 1989; 13: 275-82.

[19] Canavese F, Wright JG, Cole WG and Hopyan SJ. Unicameral bone cysts: comparisonof percutaneous curettage, steroid, and autologous bone marrow injections. J Pediatr Orthop 2011; 31: 50-5.

[20] Malkawi H, Shannak A and Amr S. Surgical treatment of pathological subtrochanteric fractures due to benign lesions in children and adolescents. J Pediatr Orthop 1984; 4: 63-69.

[21] Dormans JP, Hanna BG, Johnston DR and Khurana JS. Surgical treatment and recurrence rate of aneurysmal bone cysts in children. Clin Orthop Relat Res 2004; 205-11.

[22] Parekh SG, Donthineni-Rao R, Ricchetti E and Lackman RD. Fibrous dysplasia. J Am Acad Oorthop Surg 2004; 12: 305-13.
[23] Ippolito E, Bray EW, Corsi A, De Maio F, Exner UG, Robey PG, Grill F, Lala R, Massobrio M, Pinggera O, Riminucci M, Snela S, Zambakidis C and Bianco P; European Pediatric Orthopaedic Society. Natural history and treatment of fibrous dysplasia of bone: a multicenter clinicopatho-logic study promoted by the European Pediatric Orthopaedic Society. J Pediatr Orthop B 2003; 12: 155-77.
[24] Almeida Herrero F, Silvestre Muñoz A, Martinez Rodriguez M and Gomar Sancho F. Ossifying fibroma of long bones in adults: a case report. Acta Orthop Belg 2006; 72: 786-9.
[25] Kempson RL. Ossifying fibroma of the long bones. A light and electron microscopic study. Arch Pathol 1966; 82: 218-33.
[26] Campanacci M and Laus M. Osteofibrous dysplasia of the tibia and fibula. J Bone Joint Surg 1981; 63-B: 367-375.
[27] Lee RS, Weitzel S, Eastwood DM, Monsell F, Pringle J, Cannon SR and Briggs TW. Osteofibrous dysplasia of the tibia. Is there a need for a radical surgical approach? J Bone Joint Surg Br 2006; 88: 658-64.
[28] Rahman MA, El Masry AM and Azmy SI. Review of 16 cases of aneurysmal bone cyst in the proximal femur treated by extended curettage and cryosurgery with reconstruction using autogenous nonvascularized fibula graft. J Orthop Surg (Hong Kong) 2018; 26: 2309499018783905.
[29] George B, Abudu A, Grimer RJ, Carter SR and Tillman RM. The treatment of benign lesions of the proximal femur with non-vascularised autologous fibular strut grafts. J Bone Joint Surg Br 2008; 90: 648-51.
[30] Gibbs CP Jr, Hefele MC, Peabody TD, Montag AG, Aithal V and Simon MA. Aneurysmal bone cyst of the extremities. Factors related to local recurrence after curettage with a high-speed burr. J Bone Joint Surg Am 1999; 81: 1671-8.